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ASSOCIATION OF ENGINEERING SOCIETIES.

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COMPOUND MARINE ENGINES FOR LAKE SERVICE.

BY WALTER MILLER, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read August 11, 1885.]

It is not the intention in this paper to give a history of the lake marine, but to briefly give some idea of what has been and what is now being accomplished. It is only in the last few years that the compound engine has come into general use. Five years ago, low and high pressure condensing engines were the rule, and the compound the exception; while to-day it is just the reverse; and it will be safe to say that within the next five years the lake marine will have made an entire revolution, which will result in larger and more complete engines being built.

The compound engine is not generally understood by those who are not directly interested in its designing or building. Nevertheless, the subject is a very interesting one, and should be better understood by engineers, for the reason that the thousands of stationary engines now working high pressure should be compounded, and eventually they will be built compound high pressure, or condensing.

These compound engines were introduced into the lake marine very soon after they came out on the coast, but they came into use slowly, and it was a serious question for a long time if there was any benefit derived from their use; and in comparing the old style of compound with that of the present time, it is not a very difficult matter to see that the gain could not have been near what it is at present. Engine-builders were backward in expressing any decided opinion about their economy, for the reason that they did not want to try any experiments; besides, they were not satisfied in their own minds as to the degree of economy they would effect. They had their old designs and patterns of single and double high pressure and condensing engine which they had been building for years; and knew how to take every advantage, both in building, operating and making the most money out of them. As an instance, to show how reluctant engineers were in those earlier days to commit themselves: Erastus Smith, a well-known mechanical engineer of New York city, who had built a number of compound engines and was considered an authority on the subject, but whose days of working for

glory had gone by, when asked by a party who wanted to design a first-class engine for a fine yacht, and who wanted to get all the data he could, which engine was the best to adopt, replied: "That other engineers might do as they liked; but as for himself, he was now working for Erastus Smith." But the fact that an engine once built as a compound had never been changed to the old form, led vessel men to think that there was something in the compound principle. Engineers reported that they seemed to work more smoothly, and were more easily taken care of, and thought they could see a difference in the coal consumed. Thus by its continued use and improved proportions, it is now no longer a question which is the best. Take the condensing engine, with its extremely short cut-off, making it almost impossible to keep it in good working condition, with steam expanded to its lowest possible limit, leaving the temperature of the steam at the termination of the stroke far below that of the incoming steam, which would have to lose a large part of its heat by coming in contact with the cool cylinder; and the condensed steam thus formed would have to be in turn re-evaporated, and before it has time to be of any use, the exhaust opens and the whole is swept into the condenser and lost. Steam can be expanded to advantage four times, in a single cylinder; and for mechanical reasons, as well as that of economy, it should not be carried farther than this: while with the compound engines of the type now used on the lakes, steam can be expanded twelve times. With its large volume of steam in the small cylinder, by reason of longer cut off equalizing the strains on connections and framing of the engine, never expanding so low but what any condensation and re-evaporation that may take place will be utilized in the large cylinder, and when the triple compound with its higher steam pressure comes into use here (as it is certain to do), it will be still more favorable to working steam expansively, and instead of twelve expansions, we may see eighteen or twenty.

There are, always, seemingly insurmountable difficulties that will arise in any new enterprise, which by continued use will soon disappear, and in looking back we will wonder why we should have blundered at all. In the earlier compounds, complications arose that seemed very difficult to overcome, but by persistent effort and use the compound engine is as simple and much easier handled than any of the old-style condensing engines in their palmiest days. It was the boast of the old school of engineers that they could design condensing engines without any of the complications (as they termed them) of the compound, and as a result they brought out some fine engines that worked well for a time; but, as stated before, they could not be maintained for any length of time, by reason of the extremely short cut-off, and the steam pressure had to be lowered and allowed to follow the piston farther before cutting off. In the earlier compounds it was thought an empirical rule that the receiver space should be in exact ratio to the high-pressure cylinder, and if the engine was of the fore-and-aft class, elaborate calculations would have to be made to get the exact proportion of receiver space between cylinders. In practice, however, it has been found that by placing the cylinders close together and laying out the passages from one cylinder to the other, enough receiver space will then be formed—in fact, more than will

be wanted. It is the practice at the present time to simply convey the steam from one cylinder to the other with a pipe of the same area as the exhaust port of the high-pressure cylinder, by this means avoiding all complicated cylinder castings. In case the engine was of the steeple or tandem class, great care had to be taken to have no waste room in the steam passages leading from the small to the large cylinder, as it was all a waste ; and the fact was lost sight of that as the steam expanded and its volume increased, it would have a much lower velocity, and therefore required larger and freer passages from one cylinder to the other. With the small passages an excessive amount of back-pressure was produced in the small cylinder, and a very low initial pressure in the large cylinders, which increased what is known as the gap between the back-pressure line of the high and the steam line of the low-pressure cards. By making the passages large and free, the loss of pressure can be made up by increased lap on the valve of the large cylinder ; and on the fore-and-aft engines a cut-off valve is used on the back of the main valve of the large cylinder by some builders to keep up the pressure between the cylinders to the highest point possible, equalizing the work done in each cylinder, and preventing idle expansion and loss by lower temperature of the steam. The steam should be worked in the low-pressure cylinder in the same manner as it is in the high-pressure. There should be no difference, as all above the vacuum line is pressure, and should be treated as such. Cutting off in the same manner in the large cylinder will result in keeping up the pressure between the cylinders nearly to that of the terminal pressure of the small cylinder, and bring up the steam line of the large cylinder. Indicator cards taken on a trial of a recently-built triple compound in England, show the steam line of the second cylinder to go above the terminal pressure of the first cylinder the moment the exhaust opened, by reason of lap and compression on the valve of the second cylinder, thus equalizing the work done in each cylinder and preventing any idle expansion in the receiver space. Records kept by the British Lloyds show a gain of from twenty-five to seventy-five per cent. since the introduction of the compound engine. This gain is not all due to the plan of compounding, but is in part due to the higher steam pressure used, as well as the improved methods of working the steam more expansively. English engineers think they have reached the limit of economy in the present plan of compounding, and are now using higher steam and triple cylinders—in fact, are changing the older styles of compounds to this form, and are effecting a gain of twenty-five per cent., while we of the lake marine have begun to compound low-pressure engines successfully.

To give some idea of what can be saved by compounding high pressur and condensing engines, I will state the following, which is as fair a test as could be made. The first was a high-pressure engine, 30-inch bore × 30-inch stroke, carrying steam from 90 to 100 pounds, cutting off at 10 inches of the stroke, turning a wheel, of given diameter and lead, a given number of turns. This cylinder was replaced by a 24-inch high and 44-inch low-pressure cylinder by 30-inch stroke, with air pump and condenser added. This engine made the same number of turns as before, cutting off at 10 inches, same place as in 30-inch cylinder; steam pressure, diameter and

lead remaining the same, there being a saving of 36 per cent. in volume of steam admitted to the high-pressure cylinder; besides, the boiler could make steam with a much cheaper grade of coal than formerly. The second was a double 36-inch × 36-inch × 46-inch stroke condensing engine, carrying steam at 58 pounds, cutting off at 10 inches in each cylinder, making a given number of turns, with a wheel of given diameter and lead. These cylinders were replaced by 30-inch and 50-inch cylinders and 46 inches stroke. This engine made the same number of turns as before, diameter and lead of wheel remaining the same, cutting off at 20 inches in the 30-inch cylinder, and effecting a saving of 25 per cent. of the volume of steam admitted to the high-pressure cylinder. It did even better than this; the pressure in the boiler was raised from 58 to 68 pounds by the inspector, on account of the boiler being double riveted. The engine made the same number of turns as formerly, cutting off at 17 inches. This was done without any refinement of engine building in one case more than the other, both being a fair sample of the lake marine work. The two cases are mentioned here to compare with a form of engine that was at one time considered the best.

The compound is peculiarly adapted to the vertical inverted cylinder class. In large engines the valve motion must be strong and direct, with straight eccentric rods and valve stems. All should work true and fair. On the large cylinder this can be easily done, as the valve faces will be out far enough to allow the link motion to be suspended fair and have the eccentrics clear the main journals. With the small cylinder the valve faces and link motion can be set out far enough to clear the main journal by lengthening the steam chest. This makes the steam ports somewhat longer than the old way; but they are straight and more direct, and the extra steam used is utilized in the large cylinder; with straight eccentric rods; and valve stems and links suspended from the end with double parallel bars, instead of suspended in the middle and only one bar, will soon convince those who consider the link a mechanical make-shift, and only tolerated because nothing better can be found to take its place, that they are mistaken, for the links when made as described above, are the finest mechanical motion about the engine, and as used on most of the large marine engines of English and Scotch build seem to be perfection. The reversing of the marine engine has always been a problem, and to accomplish it all sorts of arrangements have been devised. With double engines working at right angles it was not so difficult, as the engine could be worked to the right position, where the weights of the valves would balance each other; and by a turn or two of the reversing wheel the engines could be reversed with ease. But with the compound, the case was different, as it is almost like a single engine in starting. The piston of the small cylinder has to move that of the larger one until steam is worked over from the small one and a vacuum formed. In engines with cranks at right angles, this difficult is overcome by using what is called a starting valve, by means of which steam can be admitted at either top or bottom of the large cylinder, and thus work the crank of the high-pressure cylinder off the centre and to the right position for reversing. But with this arrangement the reversing was slow and laborious, and in the case of engines with cranks diametrically opposite, it became absolutely necessary that

something more powerful and rapid be used, as the large piston, when the vacuum was formed and the throttle valve closed, would continue to move until it got on the centre and would have to be barred off; and in the interval great damage might be done to the vessel or docks. This difficulty has been successfully overcome by using steam to reverse with. A cylinder is located on the engine frame and connected to an arm on the reverse shaft; and by moving a small valve on the reverse cylinder, connected in such a manner that when it is opened by the engineer and the piston begins to move, the small valve will close the steam port and the piston will stop in any position, the reverse lever may be placed. By this arrangement the engine working under full steam can be instantly reversed from full gear ahead to full gear backing, or the links moved in mid gear and the engines held in check.

Some knowledge of the immense size the marine engine has reached may be obtained from the fact that an engine built in England a short time ago had a steam cylinder for reversing thirty-two inches in diameter. It is by means of these improvements only that engines of ten and twelve thousand horse-power can be controlled. The largest compound on the lakes at the present time is 35 inches high and 70 inches low-pressure cylinder by 48 inches stroke; and one as small as 8 inches high and 14 inches low-pressure cylinders by 12-inch stroke, and works as complete as the larger engines. When comparing engines of the lake marine with those built by English and Scotch builders and those on the coast, a vast difference is found in the weight and strength of engines of the same size. Those on the lakes are much the lighter—in fact, they are built on the banjo principle, while the others are built on the anvil principle; one is strong and massive, while the other is light and graceful, but begins to spring when heavy work is thrown on it. Some builders lay claims to making the working parts of their engines of steel to reduce the weight. This is a mistake. Stiffness is of more importance. If the crank shaft springs and heats, it is little satisfaction to know that it is made of steel. A piston or connecting-rod that trembles is a continual source of annoyance, and any amount of assurance that they are of steel will not satisfy the engineer that they are safe. The engines were originally designed to work with 50 and 60 pounds of steam, and at the present time are using a steam pressure of 100 pounds without one pound additional weight in the engines. The board of experts on the trial of the United State dispatch boat "Dolphin" reported that when it was attempted to work the engines to their full power, streams of water had to be run on the journals continually. It does not take very much spring in a shaft 10 inches in diameter with journal 1½ diameters long to seriously affect its alignment. And when a power of 500 horse-power is exerted every time the crank passes the centre, there must not be any lack of material at the proper place to keep things from springing. It would seem when an engine showed signs of distress, that there would be danger of something giving way. There is danger, no doubt; but the moment any weakness is discovered by the engineer, every care is taken to favor that particular place, and the engine may run for years without a serious break-down. The banjo principle in some classes of construction is a good one, but nothing short of the anvil principle should be permitted in marine engines.

As remarked at the beginning of this paper, the next five years will show a vast change in the engines of the lake marine. They will be stronger, heavier and more complete in detail. Although there have been some fine engines built on the great lakes, we have still much to learn in the manner of designing, but when a comparison of the economy of fuel consumed is made with engines built on the coast and in England, they will compare very favorably. In their regular work they will develop a horse-power per hour on 1¾ pounds of coal, and when the triple compound comes into general use, one horse-powor developed per one pound of coal per hour may be looked for.

NARROW *VERSUS* BROAD ("STANDARD") GAUGE.

THE RELATIVE EXPENSES OF SOME ITEMS OF OPERATING UPON NARROW AND BROAD GAUGE RAILROADS.

By C. H. Hudson, Member of the Western Society of Engineers.

[Read November 3, 1885.]

The question of Mr. Nicholl, General Manager of the East & West R.R. (narrow gauge), why the narrow gauge is not the proper one, because his cars, weighing about 16,000 pounds, will carry as much load (paying freight) as the heavier car of the broad gauge lines, opens a much argued subject—one perhaps settled in the minds of many; but I will venture a few comparisons of the cost of working the East & West road, and a broad gauge In these comparisons we will take the equipment of the E & W. *as it is*, and such broad gauge equipment as is being used extensively. Coal cars will be taken upon each, of same capacity, while for engines we will take the "Consolidation" for the broad gauge, and the "Mogul" engine now in use on the E. & W. for the narrow gauge. We will not consider the cost of construction of roadbed.

The comparison will be much as follows:

	Broad Gauge	E. & W. R. R.
Engines	Consolidation.	Mogul.
Cylinders	20 in. x 24 in.	12 in. x 20 in.
Diameter of driving wheel	50 in.	48 in.
No. of drivers	8	6
" " truck wheels	2	2
Weight of engine ready for road	104,000 lbs.	45,000 lbs.
" on drivers	94,000 "	37,000 "
" " each driver	11,750 "	7,500 "
" " " truck wheel	5,000 "	4,000 "
" of tender loaded	44,000 "	34,000 "
No. of wheels	8	8
Weight per wheel	5,500 lbs.	4,250 lbs.
Total weight of engine and tender	148,000 "	79,000 "
Ratio of weights to small engine	1.87	1
Per cent. of large engine weight	100	53.4

We will assume that the same boiler pressure is carried and that the

same pressure is obtained in the cylinders, and we have the traction force of the engines calculated in the usual way:

	Broad Gauge.	E. & W. R. R.
$\frac{(\text{Diam. of cyl.})^2 \times \text{stroke}}{\text{diam. driv. wheel}} \times \text{pressure} =$		
$\frac{(20)^2 \times 24}{50} \times 100 =$	19,200 lbs.	......
$\frac{(12)^2 \times 20}{48} \times 100 =$	......	6,261 lbs.
Ratio	3.067	1

The relations of the cars will be as follows:

Weight of car (actual)	20,500 lbs.	15,500 lbs.
" " trucks	10,000 "	7,800 "
" " body	10,500 "	7,700 "
Capacity of car	40,000 "	40,000 "
Weight of car and load.	60,500 "	55,500 "
Per cent. of paying load	66.1	72.1

This, at first sight, would seem to indicate that the E. & W. equipment was more economical than that of our broad gauge roads. The story, however, is only half told. We will carry our comparisons further, and assume a grade upon which the E. & W. engines can haul 10 full loaded cars.

We will have weights as below:

Weight of E. & W. engine and tender...	....	79,000 lbs.
" " 10 cars and loads	....	550,000 "
Total weight of E. & W. train	....	634,000 lbs.

Now, the larger engines will haul 3.067 times as much as the E. & W., or:

Weight of engine and tender	148,000 lbs.	....
" " cars and loads	1,796,478 "	....
Total weight of broad gauge engine and train	1,944,478 lbs.	....
Ratio of tons, aside from weight of engines	3.24	1
We found that the per cent. of paying loads were	66.1	72.1
Which would give paying load on each train	1,187,472 lbs.	400,155 lbs.
Ratio	2.97	1
Number of trips required to take the paying load hauled by broad gauge engine..	1	2.97

To bring our comparisons to a money basis, we will now consider the various items of expense, repairs cars, track, etc., engines, train service, etc., including valuation of the plant.

Valuation.

Estimated cost of engines, based on prices of to-day	\$8,500.00	\$5,500.00
Interest one day at 6 per cent	1.63	1.05
Estimated cost of cars by M. C. B. rules..	400.00	....
We will allow 5 per cent. off of this for difference in material	......	380.00
Interest one day per car	.077	.073
Interest on *one train* cars	2.28	.73

Repairs Cars.

We will assume the cost of car repairs per mile to be $\frac{3}{10}$ of a cent, or per hundred miles, 30c.

	Broad Gauge.	E. & W. R. R.
As the E. & W. train is assumed at ten cars, our cost of repairs will be 10 × 30 cents..	......	$3.00
It will take 29.7 broad gauge cars for the train load, and at same cost per car we will have 29.7 × 30 cents..............	$8.91	.....

This on the assumption that the cost of repairs per mile is the same in both cases.

In the early days of the question of relation of paying load to dead-weight, it was thought that the weight of cars then in use was too great, and efforts were made to reduce, by cutting off unnecessary parts. In that way the weight of the cars was materially reduced. It was the fortune of the writer to study this subject and try many experiments. When a design had been found light enough and at the same time strong enough, it was pronounced good, and several hundred cars were so built. They carried the loads then in fashion, and stood up well for a while; but after a few years it was found that the repairs began to increase, and the weak spots were visible.

So, in the long run it was believed nothing was saved by the use of the light car, as increased repairs offset the little extra earnings. In the cars in question, we may find that with the shorter train of the E. &. W., repairs will be kept down to about the same amount per mile that we will find with the stronger cars and longer train. Hence our assumption.

Maintenance of Way.—For a starting point we will assume the cost of maintenance of way per train, on the broad gauge road, to be 15c. This is a fair average of actual experience.

Now, the engine is 8 per cent. of the whole weight of the train, but the weight per wheel is greater than on the cars. We will assume that the blow due this weight does twice what the same weight on car wheel will do. This would give—due the engine—the cost 16 per cent. of 15c., or 2.4c., leaving for balance of the train 84 per cent. = 12.6c., or per 100 miles: engines, $2.40; cars, $12.60; total for broad gauge, $15.

As the E. & W. engine weighs but 53.4 per cent. of the larger, the injury to track would be, in same proportion, assuming same injury per pound or per 100 miles = $1.28; but as the weight per wheel is less, we will deduct 20 per cent., which will make cost $1.03.

If one ton weight in E. & W. cars (including load) do the same damage as in broad gauge cars, we would have for cars in E. & W. train, $12.60 (cost of broad gauge train) ÷ 3.067 (ratio of weights of trains) = $4.11.

But the weight per wheel is 8 per cent. less in E. & W. than in broad gauge cars. For this less injury per wheel we will deduct 10 per cent., and we have damage due cars in E. & W. train, $3.70, which gives a total cost of *maintenance of way* for E. & W. train, $4.73.

We can now put our items together and with them the train expenses, and we will have the following statement :

Cost of Running one Trip (say 100 miles).

	Broad Gauge.	E. & W. R. R.
Engineer	$4.00	$4.00
Fireman	2.00	2.00
Conductor	3.00	3.00
Two Brakemen, $1.50 each	3.00	3.00
Hostler and wipers	.50	.50
Coal used, 4 tons, at $2.50	10.00	....
" 2 " "	....	5.00
Repairs of engine, 5c. per mile	5.00	....
" " 4c. "	....	4.00
Oil, waste, etc	.70	.60
Maintenance of way per 100 miles (see statement)	15.00	4.73
Repairs cars per 100 miles (see statement)	8.91	3.00
Interest on value of engine	1.63	1.05
" " " cars in train	2.28	.73
Total cost per trip	$56.02	$31.61
As the E. & W. takes 2.97 trips to carry the freight of the one trip of the broad gauge, we will have the cost of moving this amount	....	84.91

We have taken into consideration in this only the principal fluctuating expenses, assuming that the cost at terminals in loading and unloading, and of switching, would be the same; as would the many other items pertaining to supervision and management.

In these fluctuating expenses we have shown that it will cost the E. & W. road 51.5 per cent. more to move a given amount of paying freight than it will the broad gauge road, even with their heavier cars, answering Mr. Nicholl's question, so far as the the economy of operation of the E. & W. road is concerned when compared with the broad gauge road.

Had the power of the E. & W. road been of some other and heavier class, the excess of cost would be or might be reduced; though, I believe, in practice no narrow gauge road has power that will quite come up to the medium power of the wider roads.

It is true that many important items have been neglected in this comparison, but enough has been considered to show that the broad (standard) gauge has merits above the East & West narrow gauge, with its present equipment.

KNOXVILLE, Tenn., Oct. 20, 1885.

LOAMMI BALDWIN.

By George L. Vose, President of the Boston Society of Civil Engineers.
[Read September 16, 1885.]

No man so well deserves the name of the Father of Civil Engineering in America as Loammi Baldwin. Living, as he did, before the days of the railway system, and almost before engineering was recognized as a profession, his name is known to very few at the present time ; but there is no one man among the leaders of industrial work in this country to whom we owe more. There were very few works of internal improvement carried out in America during the first thirty years of the present century with which Mr. Baldwin was not connected ; and his two great works, the Government dry docks at Charlestown and at Norfolk, stand to-day unsurpassed among the engineering structures of the country.

In Sewall's History of Woburn, we have the following in regard to the Baldwin family :

"During the Revolutionary War, two gentlemen, natives of Woburn, attained to great eminence in society, of whom it seems a matter of right that some particular notice should be taken. To begin with the elder of the two, Col. Loammi Baldwin, he was the son of James and Ruth (Richardson) Baldwin, and a descendant in the third generation from Deacon Henry Baldwin, one of the first settlers of Woburn, and a subscriber to the 'Town Orders' drawn up at Charlestown for the regulation of the projected new settlement, in December, 1641. James Baldwin was by trade a carpenter, and is reported to have been the master workman in the erection of the Burlington meeting-house, in 1732, which building is still standing.

"Loammi Baldwin, the elder, was born at New Bridge (North Woburn), January 21, 1745. Discovering from early life a strong desire for acquiring knowledge, he was a constant attendant upon the instruction of Master Fowle, for many years a noted teacher of the grammar school in Woburn. At a more advanced period in life, with a view to obtaining an acquaintance with natural and experimental philosophy, he was accustomed to walk from North Woburn to Cambridge, in company with his schoolmate, Benjamin Thompson (afterward Count Rumford), to attend the lectures of Professor Winthrop; and, upon their return home, they were wont to make rude instruments for themselves, with which to illustrate the principles they had heard laid down in the lecture room at the college.

"At the commencement of the war, in 1775, Mr. Baldwin enlisted in the regiment of foot commanded by Col. Samuel Gerrish. Here he was rapidly advanced to be lieutenant-colonel ; and, upon the retirement of Col. Gerrish from the army in August of that year he was put at the head of the regiment, and not long after was commissioned to be colonel. This regiment was originally known as the Thirty-eighth, and consisted of eight companies, all of them stationed at the Boston lines. On the reorganization of the army, at the close of 1775, it included ten companies, and

was known as the Twenty-sixth. Till the end of 1775, Col. Baldwin remained near Boston; but in April, 1776, he followed Washington to New York City, and there we find him on June 22, at the Grand Battery, in command of the main guard. When Washington was compelled by the superior members of the enemy to evacuate New York, and to retreat to the western side of the Delaware, Baldwin with his men followed him; and, on the memorable night of December 25, they accompanied the Commander-in-chief in the desperate expedition which resulted in the capture of the Hessian troops at Trenton.

"Colonel Baldwin was honorably discharged from the Continental Army about 1777, on account of ill health. In 1780 he was appointed High Sheriff of Middlesex, being the first who held that office in the county after the adoption of the State Constitution. He also represented Woburn in the General Court for many years. He was one of the original corporators and a principal proprietor of the Middlesex Canal—an undertaking in which he took a great interest, and to which he gave a large amount of his time, the entire work being constructed under his superintendence. He was always much interested in farming, and in the cultivation of fruit: and it is to him that we are indebted for the well-known Baldwin apple, which he perfected and brought into use."

Colonel Baldwin's first wife was Mary, daughter of James Fowle, Esq., for many years town clerk of Woburn. His children by her were: 1. Cyrus; 2. Mary; 3. Benjamin Franklin; 4. Loammi, and 5. James Fowle. His second wife was Margaret, daughter of Josiah Fowle, of Woburn, and his children by her were: 1. Clarissa, the wife of Thomas B. Coolidge, and 2. George Rumford. Col. Loammi Baldwin died October 20, 1807, and is buried in the family tomb at Woburn.

James F. Baldwin, who was born in 1782, settled as a merchant in Boston, was at one time member of the Senate for Suffolk, made the first surveys for a railroad from Boston to the Hudson River, had charge of the construction of the Boston & Lowell Railroad, and was one of the commissioners for introducing water into Boston from Lake Cochituate. He died in 1862.

George R. Baldwin was born in 1798, and became an engineer. When quite a young man, he built the graceful elliptical stone arch across the Middlesex Canal, in the fine estate of Peter C. Brooks, in Medford—one of the few structures upon that work which yet remain. He was a particularly fine draughtsman, as shown by numerous plans still in existence. He designed and built the Boston Marine Railway, and was consulting engineer for the Charlestown water-works and also engineer of the water-works at Quebec. He prepared the plans for the improvement of the Shubenacadie Canal in Nova Scotia, which, although not carried out for lack of funds, were sent to England, and approved by the best engineering authority. He was also connected with the early surveys for the Cape Cod Canal, and was consulted by the State in regard to the improvement of the South Boston flats. He is still living, at the advanced age of eighty-seven years.

Loammi Baldwin, the younger, and the subject of our sketch, was born at North Woburn, May 16, 1780. He fitted for college at Westford

Academy, and entered Harvard in 1796, graduating with the famous class of 1800, in which were Lemuel Shaw, Joshua Bates, Washington Allston, Charles Lowell, Joseph Buckminster and other noted men. While in college, his inclination seems to have been toward mechanical subjects, to which, however, very little attention was paid at that time. It was during his college life that he made with his own hands a clock, which kept very good time, and was the wonder and admiration of his class. At the semi-annual visitation of the Committee of the Overseers, preceding Commencement, we find Baldwin put down as No. 9 on the list for "an exhibition in mechanics." At Commencement, he does not seem to have had any part; but, in 1806, he is recorded as vice-president of the Phi Beta Kappa, John Thornton Kirkland being president.

It was while Mr. Baldwin was in college that we find his father writing (November 4, 1799) to his friend, Count Rumford, then living in London, as follows:

"I have a favor to ask of you, my dear sir; and I feel confident that you will indulge me in the request I am about to make. I have already told you that I have a son at college whose genius inclines him strongly to cultivate the arts; and I think it rather doubtful whether he will apply his studies to either of the learned professions with that success as to become eminent. I have, therefore, thought whether it would not be best to endeavor to provide him with a place for a year or two with some gentleman in the mathematical line of business in Europe, who is actually in the occupation of making and vending mathematical and optical instruments in an eminent degree. Perhaps a character something similar to what the late Mr. George Adams, of London, was, might suit. It may be that you know of some good place. In this, I wish your assistance so far as to make inquiry whether he could get admitted, what the terms would be, what kind of rank he would be considered to have in such a place, where he might work at some branches of the business as well as attend on customers. In short, I wish to know all about it. Perhaps he may settle a profitable correspondence in trade with the same gentleman, when he comes to return to this country. He is very lively, ready and enterprising, and has ever sustained a good character. I have raised expectations of his usefulness, if I can but hit his prevailing genius."

In reply to the above, Count Rumford writes from Brompton as follows: "I have consulted with Mr. Frazer, of New Bond street, Mathematical Instrument Maker to his Majesty, and learn that the instrument making business is divided into two distinct branches in London, namely, working instrument makers and shopkeepers; and that though some few of the great shopkeepers, such, for instance, as Ramsden, Dolland, Adams, Frazer & Co., have workshops in their houses and employ some workmen, yet that by far the greater part of the articles in which they deal are made by manufacturers, who live in their own private houses and keep no open shops. Working instrument makers take apprentices, who are always bound for seven years; and, with them, they commonly receive a premium of about fifty or sixty pounds. The great dealers in mathematical instruments also take apprentices, but they have seldom opportunities of much practice in making

instruments. They learn to know the construction of them, and to judge of their merit of work and of the defects and perfection of the instruments in which they deal; and they likewise learn to take instruments to pieces, to clean them and examine their accuracy. But no instrument maker or dealer in instruments would, without a very large premium, undertake to instruct a young gentleman in the course of two or three years, and make him perfect in both branches of the trade. Mr. Frazer thinks that it would not be possible to get your son into one of the shops in London, for a term of from two to four years, for a less premium than from sixty to one hundred pounds; your son to be boarded in the house free of cost to you or to him during that period."

This scheme does not seem to have been followed any further. Like many others, Mr. Baldwin does not seem to have found out at once for what he was intended. Upon graduating from college he entered the law office of Timothy Bigelow at Groton. But even here Nature asserted her rights, and we find him constructing a fire engine, of which the village stood in desperate need; and this small machine is still in active service, after a use of over eighty years, and will to-day throw a stream over the highest roof in town. This engine was made in the shop of Jonathan Loring, directly opposite the blacksmith shop where the iron-work was done.

In a paper called the *Fireman's Standard* (published in Boston in 1884) there is a description of the above engine, from which the following is taken:

"In the year 1800, a young gentleman graduated from Harvard University, settled in Groton, and studied law. That young gentleman was Loammi Baldwin, who in 1802 built, at his own expense, the still serviceable hand fire-engine known as Torrent, No. 1. This old engine, built in the third year of our century, by private enterprise, can throw a stream through a five-eighths inch nozzle to the height of 75 feet, and when needed is manned by volunteers. The old machine has a quaint appearance, with its copper tube, on which is inscribed its name, 'Torrent No. 1,' and its ancient tool-box, which bears the date of its birth, 1802. The tub is 3 feet 6 inches long, 2 feet 2 inches wide, and 22 inches deep. On its bottom rests an oak plank, in which are set the valves, and in which stand the brass cylinders and the air chamber, the cylinders being each 5 inches in diameter and 16 inches high. A goose-neck on top of the air chamber serves as an outlet for the water; and a reel is attached to the hind part of the tub capable of carrying 100 feet of 2-inch hose, the first supply of which was made at the harness shop and sewed with waxed thread."

"At two different times within a few years," says Dr. Green, "Torrent No. 1 has done most excellent service in putting out fires, on both of which occasions it prevented a serious conflagration."

Having completed his legal (and hydraulic) studies, Mr. Baldwin opened an office in Cambridge in 1804. In this business he remained but a short time (about three years). He was fond of telling an anecdote of his experience at this period. He had a good many callers at his office, he said, but they always came to inquire where Fay's office was; and he would kindly direct them to his classmate, in the story above. The late

Judge Asher Ware, who for nearly half a century presided over the United States District Court at Portland, Me., and who died in 1873, studied law in the office of Loammi Baldwin, at Cambridge, in 1805 and 1806. It is not a little peculiar that while Judge Ware commenced the study of divinity, but, finding it not to his taste, entered the office of Mr. Baldwin and there laid the foundation for his future success as a profound jurist, his master, not finding the law to *his* taste, left it for the profession of engineering, which he so signally adorned. A somewhat similar case was that of the brothers Benjamin and J. H. B. Latrobe. The former was intended for the law, having studied and been admitted to the Baltimore bar, and afterward having opened an office and commenced practice in New Jersey. Finding, however, that this profession was not to his taste, he left it and entered the service of the Baltimore & Ohio Railroad Company, and became one of the most distinguished of American engineers. His brother, on the other hand, was educated as an engineer, but discovering later a taste for the law, entered that profession, and became equally noted as the legal counsellor for the same company.

In 1807, Mr. Baldwin closed his office in Cambridge, and went to England for the purpose of examining the various public works of that country. He had intended to visit the continent for the same purpose, but was prevented by the difficulty of reaching France from England at that time. On his return he opened an office in Charlestown, and commenced the life for which by all his tastes he was so admirably fitted.

One of the earliest works upon which we find Mr. Baldwin engaged was the construction of Fort Strong, upon what, at that time, was called Noddle's Island, the following description of which is from Sumner's History of East Boston :

"In 1814, the British policy of coast descents was extended to New England. Scattered attacks were made, accompanied by burning and pillage ; and the sails of English cruisers could daily be described from Boston. The town was in a defenceless condition ; the forts were almost useless ; and, owing to the bitter quarrels with the administration, no help had been given or was to be looked for from the National Government. The people of Boston and of Massachusetts had no mind to endure the fate of Washington, and took prompt measures to protect themselves. The old forts were to be put in order, and a new one to be thrown up on Noddle's Island. Loammi Baldwin was appointed engineer, and, entering at once upon his duties, issued his first official notice on the 10th of September (1814), requesting all volunteers to meet him at the Exchange Coffee House ; and so ready was the response that from five hundred to six hundred men were at once put to work, the various trades and crafts taking special days for their part of the labor ; and, on the 21st of September, Mr. Baldwin reported that the works were so far done that a guard was needed. On the 26th of October, the flag was raised, and the work was formally occupied and named Fort Strong in compliment to the energetic Governor of the Commonwealth. This fort was located on what was known as Camp Hill. The old barracks were removed in 1833, and the breastworks were gradually obliterated. The site of this fort was in the neighborhood of what is now Belmont Square."

In 1814, the Massachusetts Legislature chartered the Boston & Roxbury Mill Corporation: and, in 1818, work was begun on the Milldam or Western avenue, now the extension of Beacon street beyond the Common. For the construction of this road, one and a half miles long, Irish laborers were for the first time expressly imported into the country. The stone used was from the Parker Hill quarry. It was opened July 2, 1821. As a means of obtaining water power, the project was a failure; but, as a step in the future extension of the city of Boston, it was an important movement. Mr. Uriah Cotting, the projector of the work, having died in 1819, Mr. Baldwin was appointed engineer to complete the undertaking, which he did in a manner most satisfactory to the company. That this work did not meet with universal approval may be seen by the following, from the *Daily Advertiser* of June 10, 1814: "Citizens of Boston! Have you ever visited the Mall? Have you ever inhaled the western breeze, fragrant with perfume, refreshing every sense and invigorating every nerve? What think you of converting this beautiful sheet of water which skirts the Common into an empty mud basin, reeking with filth, abhorrent to the smell, and disgusting to the eye? By every god of sea, lake or fountain, it is incredible!" It would seem that the citizens of Boston did not relish the idea of bad smells in the early part of the century much more than they do at the present time.

From 1817 to 1820, Mr. Baldwin was engaged in the State of Virginia upon various works of internal improvement, which were intended to develop the resources of that great Commonwealth. In 1821, he was appointed engineer of the Union Canal, in Pennsylvania. This work extended from the Schuylkill, two miles below Reading, to Middletown, on the Susquehanna, nine miles below Harrisburg. Its length was 79 miles, exclusive of a navigable feeder on the Swatara. The summit level passed through a tunnel 18 feet wide, 14 feet high and 739 feet long. There were two reservoirs for the summit supply, containing 12,000,000 cubic feet of water, one of them covering 8 and the other 27 acres. There were two steam-engines of 100 horse-power each, and three water-wheels for supplying the summit with water, capable of raising in all 1,250,000 gallons every twenty-four hours. There were three dams for supplying the main canal with water, one across the Schuylkill and two across the Swatara. The great dam, located in a narrow gorge, through which the Swatara passes, and near the northern slope of the Blue Mountain, held an artificial lake of about 800 acres. The crib-work measured 200 feet across the stream, and 40 feet in perpendicular height, and was composed of timbers 10 by 12 inches, those at the base being of white oak, and the remainder of white pine, laid at right angles, forming squares of from 6 to 8 feet from centre to centre, firmly tree-nailed, and filled with stone, the whole being strongly fitted against the mountain at the west end. On the east side there was an abutment of stone laid in hydraulic cement, 48 feet high, and 8 feet above the top of the dam. The dam had a base in the direction of the stream of 110 feet. An embankment of stone and earth reached to the east side of the gap, a distance of 230 feet, and was 260 feet wide on the base, and 60 feet on top, being 50 feet in height and 10 feet above the dam. There were twelve sluice-

gates, about 6 feet above the bottom of the dam, each having an opening 2 feet square. The gates were of cast iron, and were raised by screws.

In the process of construction of this work, Mr. Baldwin had a long controversy with the president, Mr. Mifflin, in regard to the proper width of the canal and of the locks, the result of which was the resignation of Mr. Baldwin, and the appointment, in his place, of Canvass White, who coincided with Mr. Mifflin in his views as to the proper width for the locks. It turned out afterward that Mr. Baldwin's opinion was the correct one, and the canal was enlarged at a great expense. An elaborate description of the above work was prepared in 1830 by the late W. Milnor Roberts, who commenced his long and useful life as an engineer upon the Union Canal.

In 1824, Mr. Baldwin went to Europe, and spent a year, mostly in France, devoted to a careful examination of the most important public works in that country. He went also to Antwerp, to inspect the docks at that place. At this time, too, he laid the foundation of the largest and best professional library of engineering works that was to be found in America—a collection in which he took great pride, and to which he added, until, at his death, it had cost nearly $8,000. This library is still preserved in the old house at North Woburn. Mr. Baldwin was also very fond of pictures, and owned some of the best works of his classmate, Allston.

By 1825, Mr. Baldwin's studies and his work had already made him recognized, not only as an engineer, but also as a man of taste and sound judgment in matters relating to public buildings; and we find him at this period associated with the projectors of the Bunker Hill Monument. The first committee of the association on the design for this work consisted of Daniel Webster, Gilbert Stuart, Washington Allston, Loammi Baldwin, and George Ticknor. After various discussions as to the best general plan, and the obelisk having been selected, a committee was appointed to fix the dimensions and proportions in detail, consisting of Loammi Baldwin, George Ticknor, Jacob Bigelow, Washington Allston, and Samuel Swett. The final report of Colonel Baldwin recommended "an obelisk, or frustrum of a quadrangular pyramid, the base of which shall be a square of 30 feet on either side, to rise 220 feet from the platform or ground on which it is to be erected, to be surmounted with an apex having its upper angle 90 degrees, and to be 15 feet square at the top, the four faces being respectively opposite the four cardinal points of the compass." The foundation was to be 12 feet deep and 50 feet square, with offsets, and built of stones of large dimensions, all being in accordance with the designs of Solomon Willard

The committee spent much time in determining the proportions for the monument; and, to fix this point satisfactorily, Mr. Baldwin took them to the Boston and Roxbury Milldam, whence, across the vacant space, the surface of Bunker Hill could be seen, and fastened against the railing of the sidewalk in turn small models he had prepared of different proportions, and then, going to a sufficient distance in the oposite direction, so that the model would appear to the eye to be transferred to the hill, as if standing thereon in full size, he would study with them its effect as seen at a distance. Thus, by comparison, they were enabled to decide upon

the proper size of base and the proper rate of diminish which would seem to be most striking. In this way, they fixed upon the size and proportions which they reported. The outward form being agreed upon, the arrangement of the details and the interior construction was mainly intrusted to Mr. Baldwin. The whole report was drawn up in his own neat, uniform, and compact handwriting, the original being still preserved among the papers of the Monument Association. "It is fortunate," says Mr. Warren, in his history, "that the Association was able to have in the beginning the valuable services of Mr. Baldwin as chairman of the important committee to whom was referred the general subject of a plan for the monument."

Among the early projects in the neighborhood of Boston was that contemplated by the Salem Milldam Corporation. This company proposed to dam up the water-way at Beverly Bridge for the purpose of obtaining water power. Mr. Baldwin was appointed engineer to the company; and in an elaborate report to the Hon. John Pickering, of Salem, made in 1826, it is stated that two lines were surveyed for dams. That for the west dam was from Orne's Point to the rock east of Beverly Bridge, and was 2,180 feet long. The east dam ran from the same rock to Salem Neck, and was 3,031 feet long, passing along the south side of the Beverly channel and crossing the Collins Cove channel. The total estimated cost of the two dams was $200,000. The power thus obtained was reckoned sufficient to run forty mills, which, at $500 each per annum, would pay $20,000, exceeding by $8,000 the interest on the cost. This work, for various reasons, was never carried out.

The project of connecting Boston with the Hudson River was considered at a very early period in the present century; and, in 1825, the Legislature appointed a committee to ascertain the practicability of making a canal from Boston Harbor to the Connecticut River, and thence to the Hudson, with a view to a connection with the Erie Canal. Mr. Baldwin was appointed engineer, and made a very thorough examination of various routes, and presented a very complete report on the project, in which, among other features, it was proposed to tunnel the Hoosac Mountain at almost exactly the place of the present Hoosac Tunnel. This report was one of the most complete engineering documents of the time; and, at the end of it, the commissioners say: "It is with great satisfaction that the commissioners express their decided approbation of the efficient manner in which the engineer, Col. Loammi Baldwin, has discharged his very responsible and laborious duties. To great scientific attainments and a vast fund of intelligence acquired by the minute inspection of canals and other public works within the department of the civil engineer, in Europe and in this country, he has added the advantages of great practical experience, derived from many years' constant employment in the successful exercise of his professional skill. Indefatigable, energetic and persevering, he has achieved all that can be accomplished during the period he has been employed, in a manner highly satisfactory to the committee and honorable to himself."

The day for canals, however, was rapidly passing away; and, in 1827, Mr. Baldwin was appointed by the Governor of Massachusetts to procure surveys and estimates for a railroad from Boston to the Hudson River.

This work was put into the hands of his brother James, as the subject of our sketch had at just that time accepted an appointment which led to the two great works of his life—the naval dry docks at Charlestown and at Norfolk. These two structures were in process of building from 1827 to 1834, both being carried on at the same time and both being made from the same plans. This work was commenced under the administration of John Quincy Adams and finished under that of General Jackson, Samuel Southard being Secretary of the Navy and Commodore John Rodgers President of the Naval Board.

Directly after his appointment, March 28, 1827, Mr. Baldwin proceeded to locate the two docks, and to make the necessary plans for their construction; and, on the 12th of the following June, work was commenced at Charlestown by building the coffer dam, which was completed so far as to shut out the tides the next spring, when the excavation of the pit was begun. The bearing piles were driven during the year 1828, and the foundations were sufficiently advanced to lay the corner-stone of the masonry on the 21st of May, 1829. The dock was so far completed as to be delivered into the charge of the commandant of the yard on the 9th of September, 1833. The interior of the chamber, at the top, was 86 feet wide, and 253 feet long, to the face of the arch above the mitre-sill, being the portion that could be used for docking vessels inside of the turning gates. In addition to this the space between the turning and floating gates, 53 feet, could be used by blocking up to the level of the mitre-sill, making in all 306 feet length of dock. The width of the chamber floor was 30 feet, and the length 228 feet. The depth from the coping to the mitre-sill was 30 feet. The depth of water at ordinary high tide over the mitre-sill was 25 feet, and the rise and fall of the tide 11 feet. The surface of the site on which this dock was built was about 9 feet below ordinary high tides. The height of the coping was fixed by Mr. Baldwin, after an examination of the record of tides in Boston Harbor for the previous sixty years, at several inches above the highest that had occurred within that period. In the great gale of 1851, however, the tide rose to such a height as to overflow the dock, falling in cascades along its whole length. The entire work is of granite, of the most substantial character, all of the exposed surface being finely hammered. The cost of this dock was $677,090.

Early in the summer of 1833, the work was so nearly finished as to be ready for use; and to give additional interest to the opening of the dock, which had been six years in building, it was decided that the old frigate "Constitution" should be the first vessel admitted. The event was fixed for the 24th of June, 1833. In the midst of a vast concourse of spectators, and in the presence of the Vice-President, Mr. Van Buren, the Secretary of War, Mr. Cass, the Secretary of the Navy, Mr. Southard, and other distinguished guests, Commodore Hull once more appeared on the deck of his old ship, and superintended its entrance into the dock.

The Norfolk Navy Yard is located on the southern branch of the Elizabeth River, adjoining that part of the town of Portsmouth called Gosport, about one and a half miles from the city of Norfolk. The plan and dimensions of the Norfolk dock were the same as for that at Charlestown; but the Boston dock has since been lengthened 65 feet,

as shown by the deeper courses of masonry near the head. The Norfolk dock was commenced in November, 1827; and on the 17th of June, 1833, the ship of the line "Delaware" was taken into it, being the first national ship put into a dry dock in the United States. The work was not entirely completed, however, until March, 1834. The cost of the Norfolk dock was $943,676, the excess over that at Charlestown being due to the extra price of both stone and labor, the stone having been sent from the North, as well as most of the skilled labor.

It is strange to look back now and note the lack of engineering machinery, even so late as 1830. The pile-drivers at the Charlestown dock were worked by a treadmill, although some objection was made to putting the free-born American into a machine which had so unsavory a reputation. The derricks, too, were quite different from those of the present day; and many of the modern appliances for carrying on such work were entirely unknown. The work upon these two structures was throughout designed and executed by Loammi Baldwin, his principal assistant being Capt. Alexander Parris, well known in Boston as a prominent architect during the early part of the century.

Mr. Baldwin was particular to have his position on the government work very plainly defined. In his letter to Mr. Southard, accepting the position, he writes: "It will be a very important inquiry how extensive will be my authority. Power and responsibility ought to go together; and it is always my wish, in employments like the one proposed, to have a general control and authority over the establishment under my immediate direction. I should not like to hold a divided power and responsibility with any one, not even with my own brother." Mr. Baldwin's salary, as government engineer, was fixed by himself at $4,000 a year, with $80 a month for the expense of living when away from home, and fifteen cents a mile for traveling expenses, that being the allowance for government officers. His time was spent between the two docks, the summers being passed in Charlestown and the winters in Norfolk, his assistant, Capt. Parris, alternating with him at those two places.

Mr. Baldwin's valuable journals during his connection with the government works were unfortunately lost on one of his passages from Norfolk to Boston, by the burning of the steamer "William Penn," near Philadelphia, on the 4th of March, 1834. The boat caught fire and was run aground, the passengers making their way ashore over half a mile of mud flats, an operation not only tedious, but dangerous for a man of Mr. Baldwin's weight. By the aid of a fellow-passenger, Mr. Basil Hall, the noted English traveler, he was enabled to reach the shore in safety.

In addition to the work upon the dry docks, Mr. Baldwin was made in 1827 consulting engineer to a board of commissioners, consisting of Commodores Bainbridge, Morris and Chauncey, to examine the various navy yards, and to form plans for their future improvement. He was also engaged at various times, between 1826 and 1835, in making surveys of New York Harbor, and in determining the best location for a dry dock at that place. This work, however, was not carried out until after Mr. Baldwin's death.

In the spring of 1828 the Secretary of the Navy directed a survey and

estimate to be made for building a canal, or laying a pipe, from the Norfolk Navy Yard to Lake Drummond, in the centre of the Great Dismal Swamp, for the purpose of introducing that water into the yard. This water was of a peculiar quality, being strongly impregnated with juniper, which grows very abundantly in that place, and had a very agreeable flavor, and was well adapted for the supply of vessels. The survey was a very difficult one, a large part of it being made through an almost impenetrable swamp. The project was never carried out, Congress being unwilling to make the necessary appropriation. A water boat was, however, made, of suitable dimensions to enter the lock at Deep Creek at the end of the Dismal Swamp Canal, and so provided with valves that, when in the lock, it could readily be filled with the pure juniper water. The boat was then taken to the Navy Yard, where the water was forced on board the ships by a pump. This water was often carried to sea, and during long voyages retained its purity and sweetness in a remarkable degree. The source from which the canal received its supply was Lake Drummond, a sheet of water about seven miles long and five miles wide, the only outlet of which was the Dismal Swamp Canal. The surface of the water in the lake was about 25 feet above tide at Norfolk, and the quantity of water supplied was much more than that needed for the canal

In 1834, Mr. Baldwin made an elaborate report upon introducing pure water into the city of Boston, a second edition of which was published in 1835. In this report of seventy pages, and an appendix of as many more, Mr. Baldwin discusses rain water and cisterns, common and artesian wells, aqueducts, conduits and pumps, and refers to the water supply of ancient and of modern Rome, Constantinople, Lyons, London, Liverpool, Manchester, Edinburgh, Greenock, Glasgow, Paris, Béziers, Philadelphia, Cincinnati and Richmond. A list of the various ponds west of Boston is given, and a plan and profile of surveys from Farm and Long Ponds; and also a plan of surveys for several feeders to Jamaica Pond, by which it was proposed to increase its capacity.

In 1835, several prominent gentlemen in Maine became interested in the development of the water power of the Androscoggin River at Brunswick; and Mr. Baldwin was employed to make the necessary measurements and computations. The survey extended from a point about three-fourths of a mile above the village to an island one and a half miles below (from the Free Bridge to Cow Island). Two measurements of the river were made, one about half a mile, and the other about a mile and a half above the upper falls. From the several gaugings, 4,000 cubic feet per second were reckoned safe as the discharge which might be relied upon as constant through the year for mill power; and, with the 40 feet fall in the river at this place, Mr. Baldwin concluded that the Androscoggin at Brunswick offered a power unsurpassed by any river in New England at that time occupied. Recent measurements have confirmed the accuracy of his work.

In 1836, Mr. Baldwin made very complete surveys and an elaborate report for a canal to connect the Altamaha River, at Darien, with the port of Brunswick, in Georgia. The Altamaha is navigable for 200 miles from Darien, to the forks of the Ocmulgee and Oconee. The Ocmulgee

is navigable for 300 miles, to Macon; and the Oconee, 200 miles, to Milledgeville, the capital of the State. The Altamaha is thus the medium of communication for an immense tract of the interior of Georgia with Darien; but this place, which is on the left bank of the river, about twelve miles from the sea, has no harbor for foreign shipping. All the produce of the country had to be sent to Savannah or to Charleston, and return goods received from the same places by steamboats and small coasters. No foreign trade could be carried on. Georgia was a great State, with an enormous production, but without a port. It was to connect the immense traffic of the Altamaha with a good harbor for the most extensive foreign shipping that the Brunswick Canal in Georgia was contemplated. The length of the work was to be about 13 miles. The canal was to be 6 feet deep and 35 feet wide on the bottom, with slopes of one and a half to one, making 53 feet of width at the water level. At each end there was to be a lock 23 feet wide and 100 feet long, with counter guard gates to prevent the river at one end and the tide at the other from entering the canal when either should rise above its level. The canal was to be supplied by a sluice about four miles from the southern end, as it was reckoned that such feeding would distribute itself in either direction much better than if admitted at the end.

For the locks, a mode of construction was proposed such as had been often employed in England, and in Holland, where stone is difficult to get: namely, to make them of good hard-burned brick, building up in the side walls of the chamber, every 10 or 12 feet, a pier of stone, projected a little in front of the brickwork, and rounded off, so not to damage the boats. In the wing walls, also, horizontal courses, 2 or 3 feet apart, were to be laid, to protect the brick. The gate quoins and coping were to be of stone. The whole cost of the canal and locks was estimated to be $148,474. The work was commenced, but never completed. The cutting still exists, as far as it was made.

Samuel M. Felton, well and widely known, from his connection with many important public works in this country during the past fifty years, writes as follows in regard to Mr. Baldwin:

"In the year 1834, immediately after my graduation at Harvard, I went to Charlestown to take charge of a select school for boys, which had been established a year before by Professor Lovering. Colonel Baldwin was then about finishing the dry dock, on which he had been employed for several years. I soon became acquainted with him socially, and found him a most entertaining man, full of information upon all public works, at the head of his profession, and thoroughly animated by a laudable pride in its progress and success, often remarking that it was a high and honorable calling, and deserving recognition as such, equally with those of medicine, divinity or law. His works, and his views upon this subject, often expressed, did more than those of any other man to bring our profession prominently before the public at that time.

"About the year 1835, Mr. Baldwin asked me to undertake the instruction of some of the students then in his office, in physics, mathematics, surveying and kindred subjects. This I did, as I had leisure, and soon became so much interested myself in the matters relating to engineering that, at the end of the year, I gave up my school, and entered

the office as a regular student. I was soon put in charge of the office business; and I remained in this position until Mr. Baldwin's death, in 1838, when I took the office, completed such work as remained unfinished and took other work as it came to the office for several years.

"The principal business which was done in the office of Mr. Baldwin at this time, and which was not finished until after his death, was the investigation and computation of the water power at the milldam used by the Boston Iron Company. The decision of this question had been referred to Leverett Saltonstall, Loammi Baldwin, and James Hayward. It was a very complicated case, as the conditions of head and fall and back-water on the wheels were changing constantly. Mr. Baldwin took great interest in this case, giving it a good deal of personal supervision, until his final sickness and death. The report was afterward completed and signed by the two surviving members of the commission, and confirmed by the Supreme Court, after an attempt of the Boston Iron Company to set it aside.

"Mr. Baldwin was independent and positive in his professional opinions, and did not hesitate to enforce them anywhere and at any proper time. An instance illustrating this trait occurs to me at this moment, told to me in his library nearly half a century ago. General Jackson had, during his administration, conceived a scheme of bridging the Potomac at Washington, and had taken a great fancy to an old friend as the contractor to carry out the work. This person, however, was far from competent for such an undertaking; and, when the bridge came up in Congress for an appropriation, Mr. Saltonstall, the senator from Massachusetts, offered a resolution to refer this plan to Mr. Baldwin for investigation as to its feasibility of construction and its stability when done. Mr. Baldwin was accordingly requested, by a vote of the Senate, to come to Washington and to report upon the plan. He did so, and after a thorough investigation reported that the bridge could not be made for anything like the estimated price, and that it would not stand if built. This report did not please General Jackson at all: and Mr. Saltonstall told Mr. Baldwin that, if he had not already packed his trunk, he had better do so at once and leave, as the President would make it too warm for him to remain in Washington. Mr. Baldwin replied that he was then on his way to pay his respects to Gen. Jackson before leaving, as he felt in duty bound to do. He called, and told the President that, having finished the business for which he was summoned to Washington, he had come to pay his respects to the President, and say good-by. The general at first received him with great politeness; but, having got through with the preliminaries, the bridge, as was natural, came up as the great thing in the mind of the President, and he said: 'By the bye, Mr. Baldwin, I have read your report on the bridge; and, by the Eternal, you are all wrong. I have built and have seen built a good many bridges; and I know that the plan is a good one, and that the bridge will stand.' 'Gen. Jackson,' quietly replied Mr. Baldwin, 'in all pontoon or temporary bridge-work for military purposes, I should always yield to your good judgment, and should not venture to call it in question; but you must remember that this bridge should be built as a permanent structure, and should stand for all coming

time. And I yield in such matters to no one, when I have applied scientific principles to my investigations and am sure of my conclusions. Good morning, Gen. Jackson.' It is hardly necessary to say that the appropriation was not made, and that the pet bridge was never built, much to the chagrin of the President, but to the quiet satisfaction of Mr. Baldwin.

"Mr. Baldwin's position as government engineer upon the dry docks at Charlestown and Norfolk was not always a bed of roses. He was appointed under the administration of John Quincy Adams; but when Gen. Jackson came in there were many aspirants for the position, who set the wheel in motion to depose him by circulating all sorts of falsehoods, charging him with great extravagance in spending the government money, and other offences very heinous in the eyes of politicians. Mr. Baldwin, however, triumphed over all his enemies, and finished his great works; and they stand to-day as monuments to his fame and skill as an engineer."

In addition to the numerous works above referred to, Mr. Baldwin was consulted in regard to the dam across the Kennebec River at Augusta, Me.; he furnished very complete plans for a marine railway at Pensacola; he designed and superintended the construction of the old chapel and of Holworthy Hall, at Cambridge; he was consulted in regard to the Louisville & Portland Canal around the Falls of the Ohio; and he furnished a very elaborate plan for a stone bridge for the directors of the Warren bridge. He was consulted in regard to the Harrisburg Canal in Pennsylvania, and was one of the corporators of Cragie's bridge. In 1809 he published an exceedingly plain and well-written pamphlet of seventy pages, entitled "Thoughts on the Study of Political Economy as Connected with the Population, Industry, and Paper Currency of the United States." His remarks in this paper upon the value of improved modes of transport are very clear, and show a thorough appreciation of this matter. He is also stated to have written a very complete account of the Middlesex Canal, constructed by his father and also a memoir of Count Rumford; but neither of the last named papers can be found. His reports were prepared with the greatest care, and were models for style and remarkable for the exact and proper use of words. His constant professional activity left him little time for other engagements; but he was, in the widest sense of the term, a public-spirited man. In 1835 he was a member of the Executive Council, John Davis being Governor; and in 1836 he was a Presidential elector from what was then the Fourth Massachusetts District, and threw his vote, with the other Massachusetts electors, for Daniel Webster.

Mr. Baldwin was twice married. His first wife was Ann, daughter of George Williams, of Salem, by whom he had one son, Samuel Williams Baldwin, born in 1817, and who died at the age of five years, Dec. 28, 1822. On the 22d of June, 1828, he married for his second wife Mrs. Catherine Beckford, widow of Capt. Thomas Beckford and sister of Samuel Williams, an eminent American banker living in London. She died May 3, 1864, at seventy-seven years of age. Mr. Baldwin's house in Charlestown covered the ground now occupied by Linwood Place, standing somewhat back from the street. The house has been moved, and is

now Nos. 16 and 18 on the left-hand side of School street, going up the hill.

In person, Mr. Baldwin was over six feet in height, and superbly built. His face, as shown by an admirable portrait now in possession of the family, presents one of those rare combinations of intelligence, of manliness, and of dignity, which once seen can never be forgotten,—a face which shows, as Hamlet says,—

> "A combination, and a form, indeed,
> Where every god did seem to set his seal,
> To give the world assurance of a man."

He was, says one who knew him well, a thorough gentleman in his manner and his intercourse with others, and impressed every one as being a man of extraordinary ability and a leader. He detested sham and pretence in everything and in everybody. He had a keen sense of wit and humor, and was a most delightful story-teller and a most genial companion. He was liberal in his mode of life and hospitable at his home, where he was always glad to receive and entertain his many friends. When at work, he went into it with a will, and gave it his whole strength; but when it was finished, no shadow of it darkened his social hours.

There is a fine portrait of Mr. Baldwin by Chester Harding. It represents him in his full maturity and speaks for itself. Another portrait by Leslie shows him at a much earlier age. There is also a sketch by Allston, and a very fine bust by Powers.

Mr. G. J. F. Bryant furnishes the following list of assistants and students who at different times were in Mr. Baldwin's office. Alexander Parris, W. P. S. Sanger, Calvin Brown, Uriah Boyden, Samuel M. Felton, George A. Parker, H. K. Curtis, George M. Dexter, B. F. Perham, R. H. Eddy and G. J. F. Bryant. The students, or apprentices, as they were called in those days, paid a premium for entering the office, generally $200 a year for two years, and received some small compensation while at work in the field. When Mr. Baldwin died he left word that the apprentices were not to pay the fees remaining due. The impression left upon all of the young men who served him as assistants, several of whom are yet alive, is a feeling not only of profound respect for his talent as an engineer, but of love and veneration for him as a man.

Mr. Baldwin died on the 30th of June, 1838. About a year before his death he had a stroke of paralysis; and a second attack proved fatal. The general feeling at his death is well expressed in the obituary notices in the Boston and Charlestown papers. "To his professional distinction," says the *Bunker Hill Aurora*, "he added those virtues which adorn private and sweeten social intercourse. He was liberal in his sentiments, cordial in his disposition, and a generous contributor to the numerous benevolent objects. His death will be indeed a loss to the whole country; but in this town, where he was best known, his name will be long and gratefully remembered." "What shall we who have known him say," says the Boston *Advertiser*, "of his beneficence, generosity, nobleness of mind and spirit, and courtesy of manners? He was the delight of all circles, the gayest of the young and the instruc-

tor of the old, the playful companion or the wise counselor. We were captivated with his wit and humor. We gloried in the sternness and purity of his principles. May we be thankful that so much talent and worth were bestowed and used for the honor and the good of his country!"

Mr. Baldwin was by birth and by education an engineer. He had in a remarkable degree, says one of his pupils—himself afterward a distinguished member of the profession—what Smeaton called the knack of getting on the blind side of Nature. He certainly had the power of enlisting Nature as an aid and of turning her forces into profitable channels. Instead of fighting her, he made her an ally. He resembled very much the great masters of engineering in England—Smeaton and Brindley, and Rennie and Telford. He inherited from his father a taste for mechanical work, unbounded common sense, and an intense desire to be of use. His college studies and his legal training alike fed a strong mind with strong food. His grasp was broad, and his hold was sure. There was no such word with him as fail. The greater the obstacle with which he had to contend, the brighter shone his genius. What was so truly said of John Albion Andrew may well be said of him—*he was devoted to thoroughness of duty.* He never lost sight of the maxim of England's greatest engineer—that a man's ability is a debt he owes to the welfare of his fellow men.

CEMENT AND SILICATE OF LIME.

By D. P. Waters, Member of the Engineers' Club of Minnesota.

[Read June 12, 1885.]

In inviting your attention to a subject of this nature, whereof so much has been written by my superiors in the profession, my excuse is that in the manifold duties and studies of the engineer comparatively little time can be devoted to those branches with which he is not especially associated; and while a general knowledge of such matters is retained, yet unforeseen conditions arise which call for prompt study and investigation. Therefore, it may be that some of you may find entertainment in this paper.

Several articles have been from time to time going the rounds of the scientific and architectural journals, their special mission apparently to enlighten us as to the manipulation of cement and lime to make good mortar, depending upon certain characteristics and chemical combinations. Some of them do. Others do not. One writer, under the head of "How to make good mortar," assures us that two parts in bulk of good white lime, mixed with one of clean, sharp sand, and put away in a damp place, will combine in a week or two and form silicate of lime. Experiment has demonstrated that such a combination, independent of proportions, can never form silicate of lime. The researches of Penzholt and others prove that lime mortar never "sets." It will, of course, harden by drying and by the absorption of carbonic acid from the air, but, when placed in water after a lapse of hundreds of years, the lime and sand will separate. Not so with cement mortar. Here a true silicate of lime is formed, and

a mixture produced that will endure for ages—in fact, grow stronger as it grows older. The concrete work of the ancients bears testimony to this statement.

You will find that the ordinary text book on inorganic chemistry disposes of the subject of cement in rather a summary manner. So also does the average chemist. But the industrial portion of this great study is ever associated with the spirit of investigation and experiment, necessary elements of progress, and fostered by the perplexities arising from the application of theory to practice. This is found to be true relative to hydraulic cement. The process of preparing cement for use is explained by the majority of chemists substantially as follows:

The rock, having been found by analysis to contain the proper proportions of carbonate of lime and free silica (independent of other ingredients, such as magnesia, alumina, oxide of iron, etc.) necessary for a hydraulic product, is first calcined. During the process of calcination the carbonic acid is expelled, the carbonate of lime being changed to quick lime or *oxide of lime*.

The lime and silica remain in a free state throughout, and until the ground product is hydrated or "wet up," at which time the lime and silica unite and form silicate of lime. The alumina and magnesia, when present, become silicate of alumina and magnesia, provided there is enough silica to go around. Otherwise, they remain uncombined.

Now let us see what experiment opposes to this theory. You are to bear in mind, meanwhile, that no chemical change takes place except in the change of carbonate of lime to oxide of lime by the expulsion of carbonic acid—the lime and silica are free until hydration takes place. Experiment has proved that under no circumstances will silica and free lime unite and form silicate of lime by hydration. I refer to silica in this instance as pounded quartz, clay or fine sand, etc. Precipitated silica will combine with lime and form a silica, but this does not exist in cement. In other words, a silica that will not dissolve in caustic soda will not combine with lime. By adding hydrochloric acid to the silicate of soda, the silica is precipitated in a *gelatinous* form, and in this condition will combine with lime and form a silicate of lime. The believers in the theory that free lime and free silica exist in ground cement and combine by hydration, are very numerous, both in our own profession and among would-be experts on questions relative to this material, but in my opinion it is very much like that kind of faith which leads us to accept a Trinity. They argue that the silica exists in an exceedingly fine condition, and in *some* other way is prepared to combine with the lime. It certainly is not in a gelatinous form, because in the very nature of the theory the silica must be about the same when the cement is ground as when the rock was first thrown into the kiln, except in the case of overburning, in which event the silica would become vitrified by fusion and the cement destroyed. Let us now consider the other side of the question, which is that silicate of lime is formed *during the burning process*. The theory in this case being as follows:

During the process of calcination the carbonic acid, being volatile, is expelled from the lime. The silica, not being volatile, takes its place and combines with the lime, forming silicate of lime. This theory is advanced

and supported by the most distinguished investigators in the fields of chemistry, aside from engineers and experts. It is more reasonable and easy to understand. Among the many authorities on this side of the question, I will quote but two—one American, the other an European. C. A. Joy, Professor of Chemistry in Columbia College, says that "pulverized silica, when mixed with the alkaline carbonates, will combine with them when subjected to furnace heat, the silica taking the place of the expelled carbonic acid and combining to form a silicate, thus proving its properties as an acid."

The same authority assures us that silica will displace even sulphuric acid in the alkaline sulphates, and take its place. Any person can, by simple experiment, prove that these facts are true.

Now let us see what a still greater authority says. Henry Watts, of London, England, editor of the *Journal of Chemistry*, and author of the *Dictionary of Chemistry* (used as an authority in most universities), quotes as follows:

"Silicate of calcium forms the essential constituent of hydraulic mortars." "*Marl*, which is a mixture of clay with carbonate of calcium, forms a natural hydraulic limestone. It is best adapted for the purpose when it contains one part clay and three parts calcic carbonate. When such a mixture is ignited, silicate of calcium is formed, and the pulverized product hardens under water."

As a rule, I have found that the opinions of a few great authorites furnish safer guidance than those of a thousand inferior ones. For where the many are content to be guided by old precepts, the few are disposed to test them in the crucible of experiment; and this fact is by no means due to lack of theoretical knowledge on the part of those who halt: for there is so much self-sacrifice and apparently unremunerative labor in the attempt to improve on old theories that it is no wonder so many of us grow philosophical or careless in these matters, without some unusual incentive for exertion is presented.

Without further digression, I will endeavor to dispose of my subject by an analysis of the first theory and a support of the second, in as few words as possible.

If the clay and lime in burnt and ground cement are not *combined*, why do chemists employ acids to separate them? If a pound of cement be carefully sprinkled into a barrel of water and vigorously stirred, and the lime is *free*, why does not the water take up the lime in solution and leave the clay free on the bottom? One may stir the water a week, and by turning it off and allowing the residue to dry, the pound of cement would still be there, provided, of course, that there is not an excess of free lime in the cement; in which case the surplus would be taken up in solution, as two parts in bulk of free lime will combine, approximately, with only one of silica. I cannot find *a single support* for this theory to rest upon, while on the other hand we have seen that silica will dispel the other acids when associated with them, under intense heat, in the alkaline carbonates and sulphates, and supply their place by combining with the bases.

When we consider that silicate of lime is the life of cement and inseparably associated with all hydraulic work in our profession: that

any subject conducive to a better knowledge of the materials we use in construction should be worthy the attention of the engineer; and that silica and heat are even now being applied with startling results to other inorganic substances in nature, it may be that later on the contents of this paper may furnish some of you food for reflection.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 16, 1885:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:30 P. M., Vice-President L. Frederick Rice in the chair, twenty-eight members present.

The record of the last meeting was read and approved.

The report of the Government nominating Messrs. Charles H. Swan, Charles W. Kettell, Thomas W. Davis a Committee on Weights and Measures was presented. Mr. Thomas W. Davis declining to serve, the Government was requested to fill the vacancy. Mr. Charles W. Folsom was appointed to fill this vacancy.

The communications from the Committee of the Civil Engineers' Club of Cleveland, concerning the relation of Army and Civil Engineers in the Government Service, with the report of the Government of this Society, giving the results of correspondence with this Committee, were read and discussed by Messrs. Brooks, Carson, Manley, Hardy, Adams and Albert H. Howland.

On motion of Mr. C. W. Folsom it was voted: That the Government of this Society be requested to appoint a committe of three (one from the Government and two from the Society at large) to consider the subject, to communicate if possible with the officers of the Convention at Cleveland and to report at the next meeting. The Committee appointed by the Government consists of Messrs. L. Frederick Rice, Clemens Herschel, Thomas Doane.

On motion of Mr. G. R. Hardy it was voted: That the Society deems it unadvisable to take any action, other than has been taken, upon the questions proposed in the circular of the Committee of the Civil Engineers' Club of Cleveland, until after the report of the Committee of this Society is presented.

On motion it was voted: That the President be requested to appoint a committee of three to consider and report to the Society at the next meeting, what action of this Society is desirable in connection with the Convention of the American Society of Mechanical Engineers. The Committee appointed by the President consists of Messrs. G. W. Blodgett, G. Lanza, G. F. Swain.

On motion of Mr. Henry Manley, it was voted: That a committee of three be appointed by nomination at large, to consider the question of quarters for the Society, to present to the members by circular the advantages of such rooms as the committee may consider, and provide for a letter ballot, to be announced at our next meeting, to decide the individual preference of the members as to the place of meeting of the Society. The Committee nominated consists of Messrs. H. Manley, A. F. Noyes, F. P. Stearns.

On motion it was voted: That the next meeting of the Society be held in the New England Railway Club room.

Messrs. James Francis and Charles E. Haberstroh were elected Members of this Society.

Mr. John A. Gould, Jr., was proposed for membership; recommended by Messrs. D. Brackett and F. P. Stearns.

Mr. Christopher J. Carver was proposed for membership, recommended by D. Brackett and E. W. Howe.

President G. L. Vose read a sketch of the life and works of Loammi Baldwin.

[*Adjourned.*] H. L. EATON, Secretary.

OCTOBER, 21, 1885:—A regular meeting of the Boston Society of Civil Engi-

neers was held and called to order at 7:15 P. M. President George L. Vose in the chair, twenty-six members and three visitors present.

The record of the last meeting was read and approved.

The committee appointed at the last meeting to consider the question of quarters for the Society, and provide for a letter ballot to decide the individual preference of the members as to the place of meeting of the Society, presented the following report: The result of the ballot on the question, Shall the place of meeting of the Society be changed from Wesleyan Hall, Bromfield street, to the B. & A. R. R. Station is as follows:

Whole number of ballots received, eighty-four; affirmative, seventy; negative, twelve; two to be counted with the majority.

On motion of Mr. H. Manley it was voted: That this informal ballot be declared formal.

Mr. G. F. Swain, member of the Committee appointed at the last meeting on the Convention of the American Society of Mechanical Engineers, presented a report recommending that the Society print a description of the Boston Main Drainage Works, including a description of its Pumping Plant and some duty trials of the Leavitt engine and boilers, to be placed at the disposal of the Convention.

On motion of Mr. H. Manley it was voted: That the President be requested to add two names to this committee. Messrs. F. P. Stearns and H. L. Eaton were added.

On motion it was voted: That the Society print a description of the Main Drainage Works as recommended by the committee on the Convention of the American Society of Mechanical Engineers.

Mr. Thomas Doane, member of the Committee on the relation of army and civil engineers in the government service reported that no progress had been made.

On motion of Mr. H. Manley it was voted: That the President be requested to appoint a committee of five, of which the Librarian shall be chairman, to arrange for the transfer of the library to its new location, and report plans and estimate of cost of furnishing the new room at the next meeting.

That this committee be instructed to provide book cases for the library at an expense not exceeding $100.

On motion of Mr. J. R. Freeman it was voted: That a vote of thanks be extended to Mr. James T. Furber, General Manager of the Boston & Maine Railroad, for courtesies extended and transportation furnished the Society on its excursion to Lawrence, Sept. 17, 1885.

Messrs. John A. Gould, Jr., and Christopher J. Carren were elected members of this Society.

Messrs. Forrest L. Libbey, William T. Pierce, Dwight Porter, Ulysses S. G. White were proposed for membership, recommended respectively by H. Manley, F. P. Spalding; E. H. Gowing, E. W. Bowditch; G. L. Vose, A. E. Burton; G. L. Vose, G. F. Swain.

Mr. F. P. Stearns read a paper on a Novel Method of Leveling for Cross-sections.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

NOVEMBER 4, 1885:—The Club met at 8:15 P. M. at Washington University, with President Moore in the chair and twelve Members present.

The minutes of last meeting were approved as published.

The Executive Committee recommended that Mr. Thos. McMath be elected a Member of the Club. He was balloted for and elected.

Mr. Wm. B. Knight, of Kansas City, Mo., was proposed for membership by Messrs. Robt. Moore and Edmond Saxton.

A paper by Mr. C. W. Clark was then read, entitled "Notes on the Influence of Inclination of the Limb and of the Axis of a Theodolite on the Measurement of Horizontal Angles," and discussed at length by Prof. Johnson.

In the general discussion Mr. Hill gave the result of some tests of cement and sand bricks, mixed 4 of sand to 1 of cement. They were twenty-six days old and averaged about 125 lbs. per square inch in compression. Mr. Russell gave an instance where common clay stood 135 lbs. per square inch in tension. Various other subjects were commented upon.

Mr. Flad made a motion that the next meeting of the Club be held at Mercantile Library. Motion carried.

[*Adjourned.*] THOS. D. MILLER, Secretary.

NOVEMBER 18, 1885 :—Club met at 8 P. M., at Mercantile Library, President Moore in the chair, and seventeen members present.

Minutes of last meeting were read and approved.

Executive Committee reported favorably on the proposal of Wm. B. Knight for membership; being balloted for he was declared elected. Executive Committee recommended that the meetings be held on the first and third Wednesdays of each month during the season. On motion the recommendation was adopted.

The Secretary then read a programme for the winter:

Dec. 2.—C. M. Woodward, Theory of Ammonia Refrigerators.
Dec. 16—Thomas J. Whitman, History of the St. Louis Water-Works.
Jan. 6—J. A. Seddon, Cross Sections of Uniform Flow in River Physics.
Jan. 20—P. M. Bruner, The Use of Hydraulic Cements.
Feb. 3—Chas. C. Brown.
Feb. 17—Chas. W. Melcher, The Theory of the Sustaining Power of an Air Jet.
March 3—Robt. E. McMath, The Future Drainage of St. Louis.
March 17—A. P. Man, The Determination of Openings for Bridges and Culverts.
April 7—W. Paul Gerhardt, Disposal of Household Waste.
April 21—Geo. H. Pegram.
May 5—S. Bent Russel, Water Supply for Fire Service.
May 19—W. H. Allerdice.
June 2—Report of Committee on Smoke Prevention.

Moved and seconded that the Executive Committee confer with the Directors of the Mercantile Library in regard to providing a room for the Club in the new building, and it be authorized to purchase a share of the membership stock for the Club. Carried.

Prof. J. B. Johnson read a paper on Solar Azimuths by Transit Attachments and Base Line Measurements by the Steel Tape. General discussion followed.

On motion a nominating committee consisting of Messrs. J. A. Seddon, C. W. Melcher, Ed. Flad, J. A. Ockerson, and S. B. Russel was appointed by the Club.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

OCTOBER 6, 1885 :—The 216th meeting was held in the Society's hall, at 4 P. M., President Williams in the chair.

The minutes of the preceding meeting were read and approved.

Upon ballot, the following gentlemen were elected Members : John Watson Alvord, Henry R. Chichester, Gustav Lauritz Clausen, Abraham Gottlieb, and Barnabas Schreimer.

Prof. Cooley, for Committee on Relation of Army and Civil Engineers, requested postponement of the discussion appointed for this meeting, which was ordered.

A circular letter from the Committee of the Civil Engineers' Club, of Cleveland, on this topic, dated September 4, was referred to Committee, with power to act.

The Secretary reported receipt of photograph likeness from Mr. Henry W. Parkhurst.

The Secretary also reported receipt of a number of copies of the "Proceedings of the Annual Meeting of the Connecticut State Association of Engineers and Surveyors," one of which he had mailed to each member.

Mr. Williams presented a bill from the Association of Engineering Societies for $109, which was ordered paid.

The President introduced Mr. Henry B. Mason, who read a paper, "Railroad Oracle." A vote of thanks to Mr. Mason was passed, and a copy of the paper requested for publication.

By invitation of the President, Mr. C. A. Needham exhibited and described a model of an oiler for car journals.

Upon application Mr. Frank S. Washburn was transferred from the grade of Associate to that of Member.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

In answer to questions of Mr. T. J. Nicholl, I would beg to refer to a report I prepared and read at the National Narrow Gauge Convention at Cincinnati, 1878, "Operation of Narrow-Gauge Railroads." It was published in the *Railway Age*, November 7, 1878. The same paper, December 26, 1878, contains a communication, "The Gauge Question," and January 14, 1879, "Conundrums in Gauge Answered."

The most economical section and weight for steel rails depends chiefly upon the weight on locomotive wheels, as ordinarily the locomotive does greatest damage to the track, and is the greatest weight coming upon it. Mr. Nicholl does not give the weight per wheel of his locomotive. Its total weight is 35 tons. How much of this is carried on each driver? What is the distance between cross ties? Mr. Nicholl will find valuable and interesting articles in the *Railroad Gazette* on the question of rails, March 13, March 27, July 10, July 24, July 31, August 14, all 1885. AUGUSTINE W. WRIGHT.

In reply to Mr. Wright's queries, Mr. Nicholl says:

Returning your report of Mr. A. W. Wright—7 tons on each driver (4); ties 2 feet apart: character of traffic, ore, coal, lumber and merchandise. Below is dimensions of coal car: Body is 7 feet 6 inches × 29 feet 6 inches × 3 feet clear; weight of car, 15,184 pounds, with trucks; weight of each truck, 3,900 pounds; size of wheels, 30 inches; journals, $3\frac{3}{4} \times 7\frac{3}{4}$; floor of car, 3 feet 6 inches from rail, and on this car we have carried 24 tons of pig iron, but do not allow generally over 40,000 pounds.

NOVEMBER 2, 1885:—The 217th meeting was held in the Society's hall, at 4 P. M. Mr. Cregier was called to the chair.

The minutes of the preceding meeting were read and approved.

Two papers were read and discussed:

"Amount of Horse-Power Used in Propelling Street Cars." By A. W. Wright.

"The Relative Expenses of Some Items of Operating Upon Narrow and Broad Gauge Railroads." By C. H. Hudson.

It was voted that the next meeting should be held at 7:30 P. M.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

NOVEMBER 17, 1885:—The 218th meeting was held in the Society's Hall at 7:30 P. M. Mr. Wright was called to the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a member was presented from Mr. Maurice Seifert, Civil Engineer and Contractor, No. 75 Major Block, Chicago, indorsed by Messrs. Zellweger, Gottlieb and Wright.

A paper by Mr. E. J. Ward, "The Feasibility of an Inverted Siphon Tunnel

for Improving the Water Power of the Illinois River at Marseilles," was read and discussed.

The following resolution was adopted:

Resolved, That it is inexpedient, for the present, to hold more than one monthly meeting, and that the hour of meeting be 7:30 P. M., for the first Tuesday of each month.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

The annual election for President, First Vice-President, Second Vice-President, Secretary, Treasurer, Librarian and Trustee, will take place at the meeting, Tuesday, January 5, 1886.

Members expecting not to be present can send letter ballots.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

AUGUST 11, 1885:—Meeting called to order, President Holloway in the chair. In the absence of the Secretary, Mr. Mordecai was elected Secretary pro tem.

On motion, the reading of the minutes of the previous meeting was dispensed with.

The thanks of the Club were extended to the Association of Engineers and Surveyors of the State of Indiana, and to Mr. E. S. Corthell, of the Tehuantepec Ship Canal Co., for pamphlets received.

The Committee on Architecture was authorized to take such action upon the question of building inspection as may be deemed best, and report the same in writing at next meeting.

Lord Cecil, of the London District Underground Railroad, was introduced by the President, and gave some interesting facts in relation to the construction and operation of that road. He stated that they were using a rail similar to the double-headed rail, and weighing 86 lbs. per yard, supported by chairs upon cross-ties 2 feet 3 inches apart. The rails showed very unequal wear, some lasting 6 years, some only 6 months.

They were running 18 trains an hour over the road, spaced 3 minutes apart, with two spaces of 6 minutes each. He thought 20 trains per hour was the limit. He thought the New York Elevated roads were capable of handling more trains per day than the underground road, as they are open and above ground, and the trains can be more easily seen. They make only from 15 to 20-second stops, and he believed, therefore, that the English system of coaches, with side entrances, is better adapted to the quick handling of passengers than the American system with end doors and narrow aisles. They use the Westinghouse air brake without the triple valve. The average fare is about 4 cents per passenger.

Mr. Walter Miller read a paper on the "Compound Marine Engines for Lake Service," which was generally discussed.

The following resolution was adopted:

Resolved, That the Treasurer of the Club be, and he is hereby, authorized to pay to the Association of Engineering Societies, for the publication of the Journal of the Association, such amounts of money as shall be legally called for from time to time by the President of the Board of Managers—such amounts, in the aggregate not to exceed three dollars per member, based upon the mailing list, at the time an assessment is made.

[*Adjourned.*] A. MORDECAI, Rec. Sec'y, *pro tem.*

SEPTEMBER 8, 1885:—Meeting called to order, President Holloway in the chair. Minutes of the July and August meetings were read and approved.

The Committee appointed on the relation between the Military and Civil Engineers upon Government works, other than Military, reported progress.

Books and pamphlets received as follows:

Boston Improved Sewerage Report; American Engineering Register of Prof. L. M. Haupt; Fifth Annual Meeting of the American Water-Works Association; Abstract of the Proceedings of the Society of Arts of the Massachusetts Institute of Technology; Earth-Work Estimation, by S. B. Fisher, of the Pennsylvania Railroad; A System of Iron Railway Bridges for Japan, by J. A. L. Waddell.

The Request of Technical Society of the Pacific Slope for an exchange of publications was referred to the Committee on Library and Publications.

Mr. Charles Latimer, Chief Engineer of the N. Y., P. & O. R. R., read his paper on "Railroad Organization," which he read before the American Society at Deer Park.

Mr. A. Mordecai read a short paper, discussing the paper read by Mr. Latimer.

Mr. J. H. Sargent read a paper on "The Development of Transportation in Northern Ohio."

[*Adjourned.*] M. W. KINGSLEY, Rec. Secretary.

OCTOBER 13, 1885:—Meeting called to order, President Holloway in the chair. Minutes of last meeting were read and approved.

D. C. Henny was elected an Active Member of the Club.

A vote of thanks was tendered Col. J. M. Wilson, of Washington, D. C., for views and drawings of St. Mary's Falls canal and locks.

Committee on the Relations between the Military and Civil Engineers on Government Works other than Military reported progress, and were authorized to make arrangements for the reception of delegates to the convention, which is to meet in this city to discuss the question. Committee were instructed to report at meeting, to be held in two weeks.

Prof. Eisenmann read a paper on "Tests of Some of our Local Building Stones."

[*Adjourned for two weeks.*] M. W. KINGSLEY, Rec. Secretary.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

SOLAR AZIMUTHS BY TRANSIT ATTACHMENT, AND BASE LINE MEASUREMENTS BY THE STEEL TAPE.

BY J. B. JOHNSON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read November 18, 1885.]

In most land surveys, it is desirable to refer the directions of the boundary lines to the true meridian. The needle compass is the most common and convenient instrument for doing this: but the various secular, temporary, and local changes in the declination of the needle have resulted in its being ruled out of many departments of land surveying. All land surveys of the United States are now made with the solar compass or the transit attachment. The solar device is the only instrument with which a continuous east and west line can be run without auxiliary corrections or azimuth observations.

It has been commonly asserted, however, that the accuracy attainable in the use of the solar compass was little, if any, greater than that from the use of the needle compass when the local declination was well determined and there was no local attraction. In order to determine just what accuracy was possible with a Fauth solar attachment set on a Buff & Berger transit, I spent two days in making observations on a line whose azimuth had been determined by observations on two nights on Polaris at elongation, the instrument being reversed to eliminate errors of adjustment. Forty-five observations were made with the solar attachment on Oct. 24, 1885, from 9 to 10 A. M., and from 1:30 to 4 P. M., and on Nov. 7 forty-two observations between the same hours.

On the first day's work the latitude used was that obtained by an observation on the sun at its meridian passage, being 38° 39′, and the mean azimuth was 20 seconds in error. On the second day, the instrument having been more carefully adjusted, the latitude used was 38° 37′, which was supposed to be about the true latitude of the point of observation, which was the corner of Park and Jefferson avenues in this city. It was afterwards found this latitude was 38° 37′ 15″, as referred to Washington University Observatory, so that when the mean azimuth of the line was corrected for this 15″ error in latitude, it agreed exactly with the stellar azimuth of the line, which might have been 10″ or 15″ in error. On the first day all the readings were taken without a reading

glass, there being four circle readings to each result. On the second day a glass was used.

On the first day the maximum error was 4 minutes, the average error was 0.8 minute, and the "probable error of a single observation" was

TABLE I

A TABLE OF MEAN REFRACTIONS IN DECLINATION.

To apply on the declination arc of Solar Attachment of either Compasses or Transits.

Computed by EDWARD W. ARMS, C. E., for W. & L. E. GURLEY, Troy, N. Y.

HOUR ANGLE	DECLINATIONS.								
	+20	+15	+10	+5	0	−5	−10	−15	−20
	For Latitude 15°.								
0 h.	05″	0″	+05″	10″	15″	21″	27″	33″	40″
2	−03	−02	07	12	18	23	29	36	43
3	−01	05	11	16	22	28	34	41	49
4	08	12	19	24	30	37	44	53	1′01
5	29	31	41	49	59	1′10	1′24	1′43	2 08
	For Latitude 17° 30′.								
0 h.	−02″	+02″	08″	13″	18″	24″	30″	36″	44″
2	0	05	10	15	21	27	33	40	48
3	−02	10	15	21	27	33	40	48	57
4	13	18	23	29	35	43	51	1′01	1′13
5	34	41	49	58	1′16	1′23	1′41	2 06	2 42
	For Latitude 20°.								
0 h.	0″	05″	10″	15″	21″	27″	33″	40″	48″
2	03	07	13	18	24	30	36	44	52
3	06	13	18	24	30	36	44	52	1′02
4	17	22	28	35	42	50	1′00	1′11	1 26
5	39	47	57	1′07	1′20	1′37	2 00	2 32	3 25
	For Latitude 22° 30′.								
0 h.	02″	08″	13″	18″	24″	30″	36″	44″	52″
2	06	11	15	21	27	33	40	48	57
3	11	15	21	27	33	40	48	57	1′08
4	20	26	32	39	46	56	1′07	1′19	1 37
5	45	53	1′03	1′16	1′31	1′52	2 21	3 07	4 28
	For Latitude 25°.								
0 h.	05″	10″	15″	21″	27″	33″	40″	48″	57″
2	08	11	19	25	31	38	46	54	1′05
3	12	18	24	30	37	44	53	1′04	1 18
4	23	29	35	45	53	1′03	1′16	1 31	1 52
5	49	59	1′10	1′24	1′52	2 07	2 44	3 46	5 43

also 0.8 minute. On the second day the maximum error was 2.7 minutes, the average error was 1 minute, and the "probable error of a single observation" was 0.86 minute. The time required for a single observation is from three to five minutes.

I believe this accuracy is attainable in actual practice, as no greater

care was taken in the adjustment or handling of the instrument than should be exercised in the field.

The transit has come to be the universal instrument for the engineer, and should be for the surveyor, so it is more desirable to have the solar

TABLE I., CONTINUED.

HOUR ANGLE.	DECLINATIONS.								
	+20	+15	+10	+5	0	−5	−10	−15	−20
	FOR LATITUDE 27° 30′.								
0 h.	08″	13″	18″	24″	30″	36″	44″	52″	1′02″
2	11	16	22	28	34	41	49	1′00	1 10
3	17	22	28	35	42	50	1′00	1 14	1 26
4	28	35	42	50	1′00	1′11	1 26	1 43	2 09
5	54	1 05	1′18	1′34	1 54	2 24	3 14	4 38	8 15
	FOR LATITUDE 30°.								
0 h.	10″	15″	21″	27″	33″	40″	48″	57″	1′08
2	14	19	25	31	38	46	54	1′05	1 18
3	20	26	32	39	47	55	1′06	1 19	1 36
4	32	39	46	52	1′06	1′19	1 35	1 57	2 29
5	1′00	1 10	1′21	1′52	2 07	2 44	3 46	5 43	13 06
	FOR LATITUDE 32° 30′.								
0 h.	13″	18″	24″	30″	36″	44″	52″	1′02″	1′14″
2	17	22	28	35	42	50	1 00	1 11	1 26
3	23	29	35	43	51	1′01	1 13	1 28	1 47
4	35	43	51	1′01	1′13	1 27	1 46	2 13	2 54
5	1′03	1′15	1′31	1 53	2 20	3 05	4 25	7 36	
	FOR LATITUDE 35°.								
0 h.	15″	21″	27″	33″	40″	48″	57″	1′08″	1 21″
2	20	25	32	38	46	55	1 05	1 18	1 35
3	26	33	39	47	56	1′07	1 21	1 38	2 00
4	39	47	56	1′07	1′20	1 36	1 59	2 32	3 25
5	1′07	1′20	1′38	2 00	2 34	3 29	5 14	10 16	
	FOR LATITUDE 37° 30′.								
0 h.	18″	24″	30″	36″	44″	52″	1′02″	1′14″	1 29″
2	22	28	35	42	50	1′00	1 12	1 26	1 45
3	29	36	43	52	1′02	1 14	1 29	1 49	2 16
4	43	51	1′01	1′13	1 27	1 49	2 14	2 51	4 05
5	1′11	1′26	1 54	2 10	2 49	3 55	6 15	14 58	
	FOR LATITUDE 40°.								
0 h.	21″	27″	33″	40″	48″	57″	1′08″	1′21″	1′39″
2	25	32	39	46	52	1′06	1 19	1 35	1 57
3	33	40	48	57	1′08	1 21	1 38	2 02	2 36
4	47	55	1′06	1′19	1 36	1 58	2 30	3 21	4 59
5	1′15	1′31	1 51	2 20	3 05	4 25	7 34	25 18	
	FOR LATITUDE 42° 30′.								
0 h.	24″	30″	36″	44″	52″	1′02″	1 14″	1′29″	1 49″
2	28	35	39	50	1′00	1 12	1 26	1 45	2 11
3	36	43	52	1′02	1 13	1 29	1 49	2 17	2 59
4	50	1′00	1′11	1 26	1 44	2 10	2 49	3 55	6 16
5	1′16	1 36	1 58	2 30	3 22	5 00	9 24		

apparatus attached to the transit than to have a separate instrument. The principal advantages of this attachment are:

1. Its simplicity.
2. Its accuracy of pointing, being furnished with a telescope which is accurately set on the sun's disk.

3. In its providing that all angles be set off on the vertical and horizontal limbs of the transit, thus eliminating the eccentricity and other inaccuracies usually found in attachment circles or arcs.

4. Its small cost.

TABLE I., CONCLUDED

HOUR ANGLE.	DECLINATIONS.								
	+20	+15	+10	+5	0°	−5	−10°	−15°	−20°
	For Latitude 45°.								
0 h.	27″	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″
2	32	39	46	52	1′06	1 19	1 35	1 57	2 29
3	40	47	56	1′07	1 21	1 38	2 00	2 34	3 29
4	54	1′01	1′16	1 33	1 54	2 24	3 11	4 38	8 15
5	1′23	1 11	2 05	2 41	3 40	5 40	12 02		
	For Latitude 47° 30′.								
0 h.	30″	36″	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″
2	35	42	50	1′00	1 12	1 26	1 45	2 01	2 51
3	43	51	1 01	1 13	1 28	1 47	2 15	2 56	4 08
4	56	1 09	1 23	1 40	2 05	2 40	3 39	5 37	11 18
5	1′27	1 46	2 12	2 52	4 01	6 30	16 19		
	For Latitude 50°.								
0 h.	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″
2	38	46	55	1′06	1 18	1 35	1 57	2 28	3 19
3	47	56	1′06	1 19	1 36	2 29	2 31	3 23	5 02
4	1′02	1′14	1 29	1 48	2 16	2 58	4 18	6 59	19 47
5	1 30	1 51	2 19	3 04	4 22	7 28	24 10		
	For Latitude 52° 30′.								
0 h.	36″	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″	3′05″
2	43	50	59	1 11	1 26	1 42	2 23	2 49	3 55
3	50	1′00	1′11	1 26	1 45	2 11	2 51	2 58	6 22
4	1 05	1 18	1 35	2 10	2 28	3 19	4 53	8 42	
5	1 34	1 56	2 27	3 16	4 47	8 52			
	For Latitude 55°.								
0 h.	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″	3′33″
2	46	55	1′05	1 18	1 34	1 56	2 30	3 15	4 47
3	55	1′06	1 19	1 35	1 58	2 30	3 21	4 58	9 19
4	1 10	1 23	1 42	2 06	2 43	3 44	5 49	12 41	
5	1 37	2 01	2 34	3 28	5 15	10 18			
	For Latitude 57° 30′.								
0 h.	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″	3′05″	4′37″
2	50	59	1 11	1 25	1 43	2 09	2 47	3 51	6 04
3	58	1′10	1 24	1 42	2 07	2 43	3 45	5 50	12 47
4	1′11	1 25	1 43	2 10	2 50	3 55	6 14	14 49	
5	1 41	2 06	2 42	3 42	5 46	12 26			
	For Latitude 60°.								
0 h.	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″	3′33″	5′23″
2	54	1′04	1 17	1 33	1 54	2 24	3 12	4 38	8 15
3	1 03	1 15	1 30	1 51	2 20	3 04	4 24	7 31	24 44
4	1 18	1 34	1 56	2 28	3 18	4 50	8 53		
5	1 45	2 11	2 50	3 57	6 21	15 32			

It is also readily removed and replaced without affecting its adjustments, and is out of the way in handling and reversing the telescope. It may be attached to any transit.

The following tables are valuable in solar compass work. The first is a table of mean refractions for various declinations, latitudes, and hour

TABLE II.

ERRORS IN AZIMUTH (BY SOLAR COMPASS) FOR 1 MIN. ERROR IN DECLINATION OR LATITUDE.

Hour.	For 1 min. error in declination			For 1 min. error in latitude.		
	Lat. 30°	Lat. 40°.	Lat. 50°.	Lat. 30°	Lat. 40°.	Lat. 50°
	Min.	Min.	Min.	Min.	Min.	Min.
11.30 A. M.…… 12.30 P. M.……	8.85	10.00	12.90	8.77	9.92	11.80
11 A. M.…… 1 P. M.……	4.46	5.05	6.01	4.33	4.87	5.80
10 A. M.…… 2 P. M.……	2.31	2.61	3.11	2.00	2.26	2.70
9 A. M.…… 3 P. M.……	1.63	1.85	2.20	1.15	1.30	1.56
8 A. M.…… 4 P. M.……	1.34	1.51	1.80	0.67	0.75	0.90
7 A. M.…… 5 P. M.……	1.20	1.35	1.61	0.31	0.35	0.37
6 A. M.…… 6 P. M.……	1.15	1.20	1.56	0.00	0.00	0.00

NOTE: Azimuths observed with erroneous declination or co-latitude may be corrected by means of this table by observing that for the line of collimation set *too high* the azimuth of any line *from the south point* in the direction S. W. N. E. is found *too small* in the *forenoon* and *too large* in the *afternoon* by the tabular amounts for each minute of error in the altitude of the line of sight. The reverse is true for the line set too low.

angles, and is taken from Gurley's manual. The second was computed by myself and is valuable in indicating the errors to which the work is liable at different hours of the day and for different latitudes, as well as serving to correct the observed bearings of lines when it afterwards appears that a wrong latitude or declination has been used. Thus on the first day's observations I used a latitude in the forenoon of 38° 37′, but when I came to make the meridian observation for latitude I found the instrument gave 38° 39′. This was the latitude that should have been used, so I corrected the morning's observations for two minutes error in latitude by this table.

It is evident that if the instrument is out of adjustment the latitude found by a meridan observation will be in error; but *if this observed latitude be used* in setting off the co-latitude, the instrumental error is eliminated. Therefore always use for the co-latitude that given by the instrument itself in a meridian observation.

It must not be forgotten that a *meridian* observation is not usually a *noon* observation, as the sun is always either "slow" or "fast" of *mean* solar time. Thus on Nov. 7 the sun was over sixteen minutes fast, so that the observation had to be taken about 11 hours 44 minutes.

If the solar compass or attachment is to be used for obtaining the azimuth of a reference line, which azimuth is carried along by back sights and reversals, then the azimuth of this line should be determined at equal intervals before and after noon, and the mean result taken. This mean will be free from instrumental errors, since these errors will be of equal amounts and of opposite signs. Or, if running a traverse, if

an azimuth be taken at 8 A. M., and this used till 4 P. M., when another is taken, the intervening observed azimuths may be corrected by one-half the difference between the observed azimuth of the line at 4 P. M. and the azimuth as carried along from the 8 A. M. observation. The corrected azimuths would then be correct if no errors had been made in the work, and if the instrument had not changed its adjustments. The same would hold for observations at 9 A. M. and 3 P. M., 10 A. M. and 2 P. M., etc.

BASE LINE MEASUREMENTS BY THE STEEL TAPE.

The accurate determination of the horizontal distance between two chosen points on the surface of the ground is a difficult task. The sources of error are of two kinds: Mechanical, or those arising from the manipulation of the measuring unit and scoring and keeping the end marks, and temperature errors, or those arising from the uncertainty in the absolute temperature, and therefore length of, the measuring unit. The latter source of error is much the larger and more difficult to eliminate in accurate work. A compensating apparatus is often used, but it is expensive in first cost, and in its use: neither has such an apparatus yet been designed which will remain of constant length for different rates of change of temperature.

The greatest accuracy in proportion to the time and money expended is undoubtedly attainable with the steel tape. This should be from 300 to 500 feet in length and of "hoop-skirt-wire" size. Such a tape, 300 feet long, with attachments, costs from $15 to $20.

If absolute results are desired, there are three constants which must be determined for each individual tape, viz., the absolute length at a given temperature, or the temperature at which its graduated length is standard; its coefficient of expansion; and its modulus of elasticity. None of these may be safely assumed.

The absolute length is the most difficult to obtain. The best way of finding this would be to compare it with some other tape of known length. But at present it is not known that such a standard exists.* If there were such a one it would not remain a standard if used in the field. The straightening of every bend where the tape has taken a set results in lengthening the tape, and such accidents are sure to happen to the tape when used in the field. It may be used for measuring a standard base-line whose length has already been determined, and so its absolute

* The writer has been informed since the reading of this paper, that the absolute length of the 300 foot steel tape belonging to the Mississippi River Commission, the coefficient of expansion and the modulus of elasticity of which the writer himself determined in 1880, has now been obtained. This was done by measuring a part of the Olney Base Line with this tape, using the method herein outlined. This base is situated in Southern Illinois, and forms the southern extremity of U. S. Lake Survey primary triangulation system. The probable error in the length of the base, from the original measurements, was about one one millionth. It is said the recent tape measurements are remarkably accordant, so it is highly probably the length of this tape is accurately known. It should therefore be no longer used in the field, but kept as a standard. This work, together with the measurement of several secondary base lines, was done by the employees of the Missouri River Commission, and when these results are made public they will doubtless demonstrate the possible accuracy of steel tape measurements far beyond all precedents.

length found; or it may be compared with a shorter standard in sections, by means of a comparator fitted with micrometer microscopes.

The coefficient of expansion can best be determined also by comparison with some other standard, but in the absence of this a set of observations would have to be made through a sufficient range of temperatures by mounting microscopes on solid pillars the length of the tape apart, and protecting the tape in such a manner as to enable its mean temperature to be accurately determined. If out of doors it would have to be inclosed in a dry wooden box. If the box is wet the variable evaporation from it will leave the temperature uncertain. The observations would have to be made continuous, if out of doors, throughout the twenty-four hours, in order to get the daily range of temperature. The writer made such a series of observations a few years ago on a 300-foot steel tape, continuing them through four days and three nights. The coefficient of expansion was found to be 0.00000699 for 1° F.

The modulus of elasticity is easily found by stretching it with different weights and observing the change in length.

Assuming that these three constants have been found, a method of doing the field work to find the length of a line to an accuracy of 1 in 200,000, or 1 in 300,000, is as follows:

1. Drive a line of stakes on line, bringing their tops approximately to some grade. This grade may be anything desired, but the upward changes should occur at the marking stakes, so that in stretching the tape it will not be lifted from its supports. The stakes should be about 25 feet apart, with one face carefully in line, or at least within an inch of the line. Determine on a set of grades that will be convenient, and that will keep the tape at least one foot above the ground. Drive nails in the sides of the stakes that are in line on the grades fixed upon. An approximate profile of the line is helpful in fixing on these grades. On these nails hang hooks about two inches long, such that the tape can be readily inserted and removed. These hooks, turning freely about their supports, will eliminate all friction when adjusted to a vertical position. The 300-foot stakes (if a 300-foot tape is used) should be very firm, and set with their centres on the line of the faces of the intermediate stakes, and cut off accurately to the grade of the tape when hanging in the hooks. An auxiliary stake is driven some 3 feet each side of this marking stake on which to rest the hands in stretching the tape. The marking stakes should have a breadth of about a foot to allow for variations for temperature. If the end graduations fall off the stake, however, one of the subdivisions of the last foot can be chosen and recorded.[1] After these stakes are all set and nails driven, the profile should be accurately taken by a level, holding the rod on the nails, and the length of the hooks above the marking stakes. This will enable the correction for grade to be computed with great accuracy.

[1] In the work done by the Missouri River Commission, strips of zinc were fastened to the tops of the marking stakes and the scratches made on these. The records of the several measurements were thus kept and carried to headquarters and filed with the notes. Since the mean temperatures of different measurements would be different, the corresponding markings on the zinc would not be coincident, but they should differ by the temperature correction for the difference in temperature. An absolute check on the field work is thus kept on file in the office.

The tape should be stretched by a pull of from ten to sixteen pounds. This can be done by the aid of an ordinary pair of spring balances.*

The temperature should be read from at least three standard thermometers, placed so as to have equal weights on the temperature of the tape, as at the 50, 150 and 250 foot marks on a 300 foot tape. Since the uncertainty in knowing the absolute mean temperature of the tape will be the greatest source of error in the measurement, so it requires the greatest care in its elimination. If the temperature error is to be reduced to 1 in 300,000, then the mean temperature of the tape must be known to within one half a degree Fahr. On a clear, or windy day, or when the air and ground differ in temperature many degrees, it is impossible to obtain the temperature of the tape to anything like this accuracy. In fact, in case of even a gentle wind, the varying temperature of the tape is so great and rapid that when one end is held to place the other swings back and forth over an eighth of an inch or so, making it difficult to decide where to set the mark. For great accuracy, therefore, the work must be done on cloudy and still days, or at night. Days may usually be chosen such that the absolute mean temperature of the tape may be found to less than half a degree.

The record of the position of the end graduations are conveniently kept on the tops of brass or copper tacks driven into the marking stake approximately in position after the tape is stretched, and then a line cut by a knife when all is ready. It is important to avoid pressing on the marking stake in any manner. The end posts should be very firm. They should be made of large timbers set several feet in the ground if the base is to be measured several times, or if the points are to be used for some time. Stones may be then set beyond these posts and the distance measured to them by plumbing if they are beneath the surface.

It is important that the friction of the tape be eliminated by some means, and it is thought the means here suggested is as cheap and effective as any. If the stakes were sawed off to grade and some kind of roller arranged for supporting the tape that would be practically frictionless it would suffice as well.

The writer's class of engineering students measured a base line, at Montrose, Iowa, in June last, by the foregoing method, supporting the tape every fifty feet, with the results given on the following page.

The temperature on June 3 varied from 76° to 80°, being cloudy and calm. On June 8 the conditions were still more favorable, the temperature varying between 55° and 58°. The end and intermediate marking stakes were not as firm as they should have been for the best results.

In the experiments made by the writer to determine the coefficient of expansion of the 300 foot steel tape belonging to the Missouri River Commission, and which was used on the Missouri River work, the pull was obtained by suspending a sixteen pound load by means of a wire passing from the tape through a cord support, which was kept at an angle 45 degrees to the horizon. The horizontal and vertical pulls were therefore equal.

In the work on the Missouri River, a still better method was employed. It consisted in suspending the weight from the forward side of a square block, or board, the tape being attached to the upper face. The block was pivoted on a knife edge at its lower rear corner, equidistant from the lines of the vertical and horizontal forces, and the block was moved by a screw until its upper face came into a horizontal position, as shown by a level bubble.

Date.	Measured length.	Sag, pull, grade corrections.	Temp. correction.	Total correction	Corrected length.
	Ft.	Ft.	Ft.	Ft.	Ft.
June 3	2,209.730	−0.441	+0.245	−0.196	2,209.534
" 3	2,209.792	−0.441	+0.212	−0.229	2,209.56[illegible]
" 8	2,210.067	−0.441	−0.101	−0.542	2,209.525
" 8	2,210.043	−0.441	−0.074	−0.515	2,209.528
Mean					2,209.538

From these results we obtain: Probable error of mean = 0.006 ft. = 1 in 370,000; probable error of a single determination = 0.01 ft. = 1 in 220,000 these errors resulting from the mechanical operations of measurement. What the absolute errors were it is impossible to say, since the temperature at which the tape is standard is unknown, except that it is marked standard at 62° F.

CORRECTIONS.

1. *Correction for Temperature.*—If T_0 = temperature at which the tape is standard, and T the mean temperature of the tape for the entire line, whose length is L, then we have:

$$C_T = + {}^*0.000007\,(T - T_0)\,L. \qquad (1)$$

2. *Correction for Pull.*—If P_0 = pull when the tape was compared with the standard; P, the pull in pounds on the tape in measuring, S, the area of the cross-section; and E, the modulus of elasticity, we have:

$$C_P = + \frac{(P - P_0)\,L}{S\,E} \qquad (2)$$

Here L and S must be taken in inches, since moduli of elasticity are given in pounds per square inch. For the tape the writer experimented on E, was 27,400,000. Find S by weighing the tape, and remembering that a piece of iron 1 inch square and 1 yard long weighs 10 pounds, we would have:

$$S = \frac{\text{Wt. in pounds.}}{10 \times \text{length in yards.}}$$

3. *Correction for Grade.*—If l_1, l_2, etc., be the lengths of the grades whose angles with the horizon are a_1, a_2, etc., and if L = measured length, we have

$$C_G = (l_1 \cos a_1 + l_2 \cos a_2 + \ldots\ldots + l_n \cos a_n) - L. \qquad (3)$$

4. *Correction for Sag.*—The curve of the tape would be a catenary if it had no rigidity, but the bending over the supports throws it into a sinuous line. As the sag is very small compared to the distance between supports, we may call the curve a parabola. Then taking moments about a point of support, we have the pull on the tape into the sag is equal to the weight of the tape over half the span into the distance to its centre of gravity, or $\frac{1}{4}$ the span, or if w = weight of tape per unit of length

d = distance between supports.

P = pull.

v = sag.

* This was the coefficient of expansion found for the 300-foot steel tape which the writer tested. It had best be determined, however, for each individual tape.

$$\text{Then } Pv = \frac{w\,d}{2} \cdot \frac{d}{4} = \frac{w\,d^2}{8}$$

$$\text{or } v = \frac{w\,d^2}{8\,P}$$

Now the length of a parabolic curve is $l = d\left(1 + \frac{8}{3}\,\frac{v^2}{d^2} + \right)$

Substituting for v its value from the preceding equation, we have

$$l = d\left\{1 + \frac{1}{24}\left(\frac{w\,d}{P}\right)^2\right\}$$

If the excess in length of the curve over the linear distance be the *correction* for sag, we have

$$c = \frac{d}{24}\left(\frac{w\,d}{P}\right)^2$$

This being the correction for one sag, if the supports are a uniform distance apart, then the number of such sags is $\frac{L}{d}$, and hence the correction for sag for the entire line is:

$$C_S = \frac{d}{24}\left(\frac{w\,d}{P}\right)^2 \frac{L}{d} = \frac{L}{24}\left(\frac{w\,d}{P}\right)^2$$

EXPERIMENTS TO DETERMINE FRICTIONAL RESISTANCES OF RAILWAY TRAINS.

BY C. H. HUDSON, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read December 1, 1885.]

This paper is descriptive of a series of experiments made by the writer a few years ago for the purpose of furnishing some evidence in a pending lawsuit between two railroad companies. The questions studied were the resistances of the trains and the powers of the engines. The subject was not a new one, the ground having been gone over many times; but possibly the treatment of it in this case may vary somewhat from other methods as shown by published records. The means adopted were such as we deemed best to furnish us with the information needed at the time, and, though somewhat crude, the end was attained. The experiments themselves were not as extended or varied as they probably would have been, had any other use been expected of them. Those relating to the resistance consisted in ascertaining in what time and distance a train of a given weight, and moving at a known speed upon given grades, would stop, and from the data obtained we have made our calculations.

The time was measured by watches usually used for timing horses, and to be sure that no mistakes were made they were in the hands of several people, so that in no case did less than two people observe the times taken. Distances were accurately measured in the usual way. No special pains were taken to select engines or cars in good order. The latter were taken from the side track as they chanced to stand, loaded with coal, and accurate weights taken. The engines in the same way were taken as they came, and were at liberty; but they were in good condition, and of the ordinary "American" type, of dimensions hereafter shown. The cars were ordinary flat-bottomed coal cars or gondolas,

with thirty-three inch wheels, three and one-half by six and one-half journal, brass bearings, and lubricated with black oil of rather inferior quality.

The dimensions and weights of the engines as used, and of the cars, with their loads, are as follows:

Engine No. 48.—Cylinders, 17 in. diameter, 24 in. stroke; driving wheels, 62 in. diameter, four coupled, with four-wheel truck, "American" style; tender on two four-wheeled trucks. Weight of engine on trucks, 27,450 lbs. (as it came in from the road with about three-fourths tank water and one-half tank of coal); weight on driving wheels, 46,300 lbs.; total weight, 73,750 lbs.; tender three-fourths full of water and one-half full of coal, 40,900 lbs.

Engine No. 47.—Same as 48.

Engine No. 63.—Cylinders, 17 in diameter, 24 in. stroke; driving wheels, 58 in. diameter, four coupled with four-wheeled truck; tender on two trucks, four wheels each; weight engine truck, light, 23,740 lbs.; 3 gauges water, 26,557 lbs.; weight on drivers, light, 40,960 lbs.; 3 gauges water, 46,563 lbs.; total weight, light, 64,700 lbs.; 3 gauges water, 73,120 lbs.; tender weight, light, 23,100 lbs.; full of water, 42,200 lbs.; full of water and 4½ tons coal, 51,200 lbs.

POSITION IN TRAIN AND WEIGHT OF CARS USED IN EXPERIMENTS, NUMBERING FROM SOUTH END.

Position.	Number.	Gross weight.
1	2,057	17,700
2	2,315	17,900
3	167	17,100
4	2,189	50,700
5	987	18,200
6	2,061	18,200
7	2,015	19,700
8	405	17,700
9	2,165	18,000
10	233	14,900
11	285	18,600
12	577	17,400
13	855	18,900
14	2,103	18,800
15	205	53,400
16	2,049	13,500
17	523	18,200
18	2,073	17,800
19	193	17,700
20	383	17,400
21	907	18,000
22	677	14,000
23	2,171	19,100
24	2,287	18,000
25	325	18,500
26	195	19,000
27	311	51,200
28	2,205	51,000
29	354	19,[illegible]00
30	2,025	17,500

Experiment 1.

Engine 48, weight	73,750 lbs.
Tender, "	40,900 "
15 cars (1 to 15, inclusive), weight	727,200 "
Total	841,850 lbs.
Length of train, including engine	533 ft.

Train got under motion on level and steam shut off at foot of 52.8 up grade, on tangent.

Speed measured by time taken to pass a base line 400 ft. long:

Seconds passing base...	23.35	Speed per hour........	11.70 mls.
Speed per second.......	17.17 ft.	Train ran by moment'm	538 ft.
" " minute. 1,028	"	Time used (estimated)..	63 sec.

Very light wind on right side nearly at right angles to train.

Unfortunately in the first six experiments no note was taken of actual time used in the stop, and we have to estimate it. We do this on the theory that the retarding force is constant (probably not exactly true in this case).

We use the formula $T = \frac{2S}{V}$, in which T = time; S = space, and V = velocity at time steam is shut off. This gives $T = \frac{1,076}{17.17} = 63$. The estimated times mentioned hereafter are calculated in this way.

Now, to estimate the resistance, which is the retarding force, we will again assume that it is constant. This would be true if the train was all on the 52.8 grade: but in fact it commences to enter that grade just when steam is shut off and when the train is on a level. We take V = velocity = 17.17: S = space run = 538; T = time (estimated) = 63. As our three items do not exactly correspond, we shall not get an exact result, but will take the three formulas for the momentum at end of first second (working from the other end, and supposing that our body moves from a stand with increased velocity till it reaches that at which, in our experiments, we start):

$$\text{First F., momentum} = \frac{V^2}{2S} = .27399$$

$$\text{Second F.,} = \frac{2S}{T^2} = .27110$$

$$\text{Third F.,} = \frac{V}{T} = .27270$$

$$.81779$$

$$\text{Average, } .27259$$

The momentum of a body in a uniformly accelerated motion at the end of the first second varies as the velocity, and the velocity varies as the power causing the velocity or motion. In case of a body affected by gravity we have, the power (weight of body) = 1, and momentum 32.

In the case of our experiments we have the momentum .27259. Upon the basis of above relations we can take the following proportions: $1 : 32 :: x : .27259$, x being the measure of amount of force causing the acceleration (or retarding), which gives = .27259.

Reduce and we have x = .008519. Now for one ton we have .008519 × 2000 = 17.038, which gives the resistance per ton causing the train to stop, providing the force acted uniformly.

As a matter of fact, the train all stood on a level save the engine itself; the tender was on the level.

The movement was 538 ft., and gravity affected the engine during the entire movement, and the tender all but its length, and so on.

Below find a table showing the weights of engines, tenders and cars, in tons, with the distance they moved on the 52.8 grade, where gravity would retard the movement at 20 lbs. per ton.

Column 1 shows engine and cars as in train. Column 2 shows weights in tons. Column 3 shows distance moved on 52.8 grades. Column 4 shows weight multiplied by distance.

1.	2.	3.	4.
Engine	36.9	538 ft.	19,852.2
Tender	20.4	518 "	10,567.2
1	23.9	486 "	11,615.4
2	23.9	454 "	10,850.6
3	23.6	422 "	9,959.2
4	25.3	390 "	9,867.0
5	24.1	358 "	8,627.8
6	24.1	326 "	7,856.6
7	24.8	294 "	7,291.2
8	23.9	262 "	6,261.8
9	24.0	230 "	5,520.0
10	22.5	198 "	4,455.0
11	24.3	166 "	4,033.8
12	23.7	134 "	3,175.8
13	24.4	102 "	2,488.8
14	24.4	70 "	1,708.0
15	26.7	38 "	1,014.6
	420.9		125,145.0

125,145 × 20 lbs. (due gravity) = 2,502,900.

Now, our estimated resistance to the ton, as given (p. 46), was 17.038 lbs. per ton.

17.038 × 420.9 (weight of train) × 538 ft. (distance moved).... 3,858,144
From which deduct amt. due gravity.......................... 2,502,900

We have.. 1,356,244
divide by 538 (distance moved) we have 2,519.04 : again divide by 420.9 (total tons) we have 5.984 lbs. for the resistance due other causes than gravity.

Experiment 2.—Same train, place and conditions.

Time passing base ...... 28.9 sec.	Speed per hour.......... 9.43 m.
Speed per sec............. 13.83 ft.	Distance run...... .....403 ft.
Speed per min..... ...830 ft.	Time (estimated)........ 58.3

As before, $V = 13.83$ $S = 403$ $T = \frac{2S}{V} = 58.3$ (estimated).

Then,

$$F = \frac{V^2}{2S} = .2373$$

$$F = \frac{2S}{T^2} = .2371$$

$$F = \frac{V}{T} = .2372$$

Average, .2372

As before, 1 : 32 : : x : .2372, and x = .0074125, or per ton .0074125 × 2000 = 14.825.

	Tons.	Distance on 52.8 grade. Ft.	Tons × distance.
Engine	36.9	403	1,4870.7
Tender	20.4	383	7,813.2
1	23.9	351	8,388.9
2	23.9	319	7,624.1
3	23.6	287	6,773.2
4	25.3	255	6,451.5
5	24.1	223	5,374.3
6	24.1	191	4,603.1
7	24.8	159	3,943.2
8	23.9	127	3,035.3
9	24.0	95	2,280.0
10	22.5	63	1,417.5
11	24.3	31	753.3
12	23.7	0	.....
13	24.4	0	......
14	24.4	0	......
15	26.7	0	......
	420.9		73,328.3

73,328.3 × 20 (effect of gravity on 52.8 grade) 1,466.566

420.9 (tons) × 403 (distance) × 14.825 2,514,656
Subtract amount due gravity..... 1,466,566

We have...... 1,048,090
Divide by 403 (distance) 2,600.72
Divide again by 420.9 (tons) 6.45
equals resistance from all other sources besides gravity.

Experiment 3.—Same train, place and conditions:

Time passing base..........	40 sec.	Speed per hour.....	6.81 m.
Speed per second	10 ft.	Distance run.....	234 ft.
Speed per minute	600 "	Time used (estimated)......	47 sec.

As before, $V = 10$ $T = \frac{2S}{V} = 47$ sec.

And again:

$$F = \frac{V^2}{2S} = .21367$$

$$F = \frac{2S}{T^2} = .21186$$

$$F = \frac{V}{T} = .21256$$

Average, .21269

As before, $1 : 32 :: x : .21269$. $x = .0066465$, or per ton $= .0066465 \times 2000 = 13.39$ lbs.

	Tons.	Distance on grade. Ft.	Tons × distance.
Engine	36.9	234	8,634.6
Tender	20.4	204	4,161.6
1	23.9	172	4,110.8
2	23.9	140	3,346.0
3	23.6	108	2,548.8
4	25.3	76	1,922.8
5	24.1	44	1,060.4

	Tons.	Distance on grade. Ft.	Tons × distance.
6	24.1	12	289.2
7	(as before.)		
8			
9			
10			
11			
12			
13			
14			
15			
	420.9		26,074.2

26,074.2 × 20 (effect of gravity)	521,484
420.9 (tons) × 13.39 (estimated momentum) × 234 (distance)	1,318,789
Due other resistance than gravity	797,305
Divide by 234 (distance)	3,407.3
Divide again by 420.9 (tons)	8.09

equals resistance per ton other than gravity.

Experiment 4.—Same train, place and conditions.

Time passing base	35.4 sec.	Speed per hour	7.70 m.
Speed per second	11.3 ft.	Distance run	316 ft.
Speed per minute	678 ft.	Time used (estimated)	56 sec.

As before, $V = 11.3$ $S = 316$ feet $T = 56$ seconds,

$$F = \frac{V^2}{2S} = .20204$$

$$F = \frac{2S}{T^2} = .20153$$

$$F = \frac{V}{T} = .20178$$

.60535

Average, .20179

Then, 1 : 32 : : x : .20179, $x = .006306$, or per ton, .006306 × 2000 = 12.61 lbs.

	Tons.	Distance on grade. Ft.	Tons × distance.
Engine	36.9	316	8,500.4
Tender	20.4	296	6,038.4
1	23.9	264	6,309.6
2	23.9	232	5,544.8
3	23.6	200	4,720.0
4	25.3	168	4,250.4
5	24.1	136	3,277.6
6	24.1	104	2,506.4
7	24.8	72	1,785.6
8	23.9	40	956.0
9	24.1	8	192.8
10	(as before.)		
11			
12			
13			
14			
15			
	420.9		44,082.0

44,082 × 20 (effect of gravity)............	881,640
420.9 (tons) × 12.64 (estimated resistance) × 316 (distance)....	1,677,185
Resistance other than gravity..................	795,545
Divide by 316 (distance)............	2,517.55
Divide by 420.9 (tons)	5.95 lbs.

equals resistance other than gravity.

Experiment 5.—Same place, time and conditions.

Time passing base........	25.6 sec.	Speed per hour...........	10.65 m.
Speed per second..... ...	15.62 ft.	Distance run....	495 ft.
Speed per minute...	937.5 ft.	Time (estimated)..... ...	63 sec.

Then, $V = 15.62$ $S = 495$ $T = 63$

$$F = \frac{V^2}{2S} = .2464$$

$$F = \frac{2S}{T^2} = .2488$$

$$F = \frac{V}{T} = .2479$$

$$.7431$$

Average. .2477

Then, $1 : 32 :: x : .2477$. $x = .00771$; $.00771 \times 2{,}000$ = resistance per ton = 15.42 lbs.

	Tons.	Distance on grade. Ft.	Tons × distance.
Engine	36.9	495	18,265.5
Tender	20.4	475	9,690.0
1	23.9	443	10,587.7
2	23.9	411	9,822.9
3	23.6	379	8,944.4
4	25.3	337	8,526.1
5	24.1	305	7,350.5
6	24.1	273	6,579.3
7	24.8	241	5,976.8
8	23.9	209	4,995.1
9	24.0	177	4,248.0
10	22.5	145	3,262.5
11	24.3	113	2,745.9
12	23.7	81	1,919.7
13	24.4	49	1,195.6
14	24.4	17	414.8
15	23.7	0	....
	420.9		104,524.8

104,524.8 × 20....	2,090,496
420.9 (tons) × 495 ft. × 15.42	3,212,687
Due other than gravity..................	1,122,191
Divide by 495	22,669
Divide again by 420.9	5.38 lbs.

resistance per ton other than gravity.

Experiment 6.—Same train and time. Train entirely upon a 52.8 grade, but engine at beginning of 2 degree curve to right when shut off, train on straight line.

Time passing base (300 ft.)	18.10 sec.	Speed per hour	11.33 m.
Speed per second	16.57 ft.	Distance run	321 ft.
Speed per minute	994 ft.	Time (estimated)	39 sec.

$V = 16.57 \qquad S = 321 \qquad T = 39$

$$F = \frac{V^2}{2S} = .42767$$

$$F = \frac{2S}{T^2} = .42208$$

$$F = \frac{V}{T} = .42487$$

$$1.27462$$

Average, .42484

Then, $1 : 32 : : x : .42484$. $x = .013277$; per ton $= .013277 \times 2000 =$ 26.554 lbs. As whole train was on 52.8 grade, the resistance due gravity = 20 lbs.; resistance other than due gravity, 6.554 lbs.

Experiment 8.—The trial was made upon level and straight track. Track was in fair condition, iron rail put up with sand (as was the track where all these experiments have been made). The joints were down somewhat, and the whole bed was much more elastic than if put up with coarse gravel or stone. Engine 47. Cars, 16 to 30 inclusive.

Base line	300 ft.	Speed per min.	1,059 ft.
Time passing base	17 sec.	Speed per hr.	12.08 m.
Speed per sec.	17.65 ft.		

Distance run .... 1,500 ft.

When engine struck down grade, train was then running at speed per second, 8.10 ft.; per minute, 486 ft.; per hour, 5.52 miles. Light wind on right-hand side and a little in rear. Train going north.

Now to estimate the time:

T, the train is in passing the 1,500 ft.

$8.1\ T =$ the space passed due the velocity at end: and $1,500 - 8.1\ T =$ the space due the retarded velocity.

Then

$$T = 2S = \frac{2\ (1,500 - 8.1\ T)}{9.55}$$

Reduce and $T = 116.5$.

We before had $S = 1,500 - 8.1\ T = 1,112.7$

$V = 9.55.$

Then,

$$F = \frac{V^2}{2S} = .08196.$$

$$F = \frac{2S}{T^2} = .08368.$$

$$F = \frac{V}{T} = .08368.$$

Average, .08311.

Then, $1 : 32 : : x : .08311$. $x = .0025973$: $.0025973 \times 2,000 = 5.194$ lbs. = resistance per ton.

Experiment 9.—Same time, place and conditions.

Time passing base (300).	26.1 sec.	Run....................	1,272 ft.
Speed per second.......	11.48 ft.	Time (estimated) going north.....................	221 sec.
Speed per minute.......	689 "		
Speed per hour.........	7.82 m.		

$V = 11.48 \quad S = 1.272$ ft. $\quad T = (\text{est.})\ 221$ sec.

$$F = \frac{V^2}{2S} = .0518$$

$$F = \frac{2S}{T^2} = .0521$$

$$F = \frac{V}{T} = .0519$$

.1558

Average, .05193

Then $1 : 32 :: x : .05193$. $x = .001623$; for one ton $.001623 \times 2{,}000 = 3.246$ lbs. = the resistance per ton.

Experiment 10.—At same place as 8 and 9. Engine 63, weight 60 tons; cars 16 to 30, weight 360 tons; total, 420 tons; length of train, 533 feet.

Time passing base (300)....	30.4 sec.	Speed per hour...........	6.73 m.
Speed per second	9.87 ft.	Run north.............	1,013 ft.
Speed per minute..........	592 "	Time, actual..............	185.5 sec.

Time estimated as 205 seconds. Light wind on side and toward rear.

$V = 9.87 \quad S = 1{,}013 \quad T\ (\text{actual}) = 185.5$ seconds.

$$F = \frac{V^2}{2S} = .04852$$

$$F = \frac{2S}{T^2} = .05888$$

$$F = \frac{V}{T} = .0532$$

1.16061

Average, 0.5353

$1 : 32 :: x : .05353$. $x = .001673$; for 1 ton $= .001673 \times 2{,}000 = 3.346$ lbs. = resistance per ton.

Experiment 11.—Same place, time and train. Same conditions, except that train moved south over same ground, the engine being in rear and same light wind tending to retard, if enough in rear (front) to have any effect.

Time passing base (300)..	33.8 sec.	Run......................	592 ft.
Speed per second........	8.87 ft.	Time, actual..............	132.5 sec,
Speed per minute........	532.2 "	" estimated..........	133.5 "
Speed per hour	6.04 m.		

$V = 8.87 \quad S = 592 \quad T = 132.5$

$$F = \frac{V^2}{2S} = .06645$$

$$F = \frac{2S}{T^2} = .06744$$

$$F = \frac{V}{T} = .06694$$

.20063

Average, .06688

1 : 32 : : x : .06688. x = .00209 ; per ton = .00209 × 2,000 = 4.18 lbs. = resistance per ton.

Experiment 12.—Same time, place, train and conditions, except run, which was north, as in 10.

Time passing base (300 feet)	27 sec.	Speed per hour	7.57 miles.
Speed per second	11.11 ft.	Run	1079 ft.
Speed per minute	666.66 "	Time	182.4 sec.
		Time (estimated)	194.2 "

$V = 11.11 \qquad S = 1,079 \qquad T = 182.4.$

$$F = \frac{V^2}{2S} = .0572$$

$$F = \frac{2\,S}{T^2} = .0648$$

$$F = \frac{V}{T} = .0609$$

$$.1829$$

Average, .061

1 : 32 : : x : .061. x = .001906 ; per ton = .001906 × 2,000 = 3.81 lbs = resistance per ton.

Mem.—Had estimated time been used we would have 3.58.

Experiment 13.—Same place, time and train. Run south.

Time passing base	26.8 sec.	Run	925 ft.
Speed per second	11.19 ft.	Time	166.4 sec.
Speed per minute	671.4 "	" (estimated)	165.3 "
Speed per hour	7.63 m.		

$V = 11.19 \qquad S = 925 \qquad T = 166.4.$

$$F = \frac{V^2}{2\,S} = .06768$$

$$F = \frac{2\,S}{T^2} = .06681$$

$$F = \frac{V}{T} = .06725$$

$$.20174$$

Average, .06725

1 : 32 : : x : .06725. x = .0021016 ; for one ton, .0021016 × 2,000 = 4.20 lbs.

Experiment 14.—On low grade. Same train as in 13. Running north. Base line, 200 ft. From south end of base line grade is .377 per 100 ft. on an average = 19.905 ft. per mile. Back of south end of base line is level.

Time passing base (200 ft.)	11.3 sec.	Run	847 ft.
Speed per sec.	17.86 ft.	Time	104 sec.
Speed per min.	1,071.4 "	" (estimated)	94.3 "
Speed per hour	12.17 "		

Wind on right side light, and a little in front.

To get at the average resistance on the basis of a uniform retardation as in the first experiments, we have :

$V = 17.86 \qquad S = 847 \qquad T = 104$

$$F = \frac{V^2}{2\,S} = .1883$$

$$F = \frac{2\,S}{T^2} = .1566$$

$$F = \frac{V}{T} = .1717$$

$$\overline{.5166}$$

Average, .1722

$1 : 32 :: x : .1722.\ x = .005381$; per ton, $.005381 \times 2{,}000 = 10.76$ lbs.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine	36.6	847	
Tender	23.4	847	
Cars 30	23.8	847	
" 29	24.7	847	156,779.7
" 28	25.5	847	
" 27	25.6	847	
" 26	24.5	847	
" 25	24.2	835	20,207.0
" 24	24.0	803	19,272.0
" 23	24.6	781	19,212.6
" 22	22.0	749	16,478.0
" 21	24.0	717	17,208.0
" 20	23.5	685	16,097.5
" 19	23.9	653	15,606.7
" 18	23.9	621	14,841.9
" 17	24.1	589	14,194.9
" 16	21.8	557	12,142.6
	420.1		322,040.9

322,040.9 × 7.54 (due gravity)..........................2,428,188.386

Now take the estimated resistance per ton above, and the weight 420.1 × 10.76 × 847 (distance)....... ....3,828,673.772

Other than gravity......................................1,400,485.386

Divide by 847 (distance).. 1,653,406

Divide again by 20.1 (tons), we have... .. ..3.935 lbs.

equals resistance other than gravity.

Experiment 15.—Same time, place and train. Light wind in front and right side.

Time passing base (200)......8.2 sec.	Run........................1,983 ft.
Speed per second..........24.39 ft.	Time.....................148.5 sec.
Speed per minute....... 1,463.4 "	" (estimated)............ 121 "
Speed per hour... ....16.63 m.	

As before, $V = 24.39 \qquad S = 1{,}982 \qquad T = 148.5.$

$$F = \frac{V^2}{2\,S} = .15008$$

$$F = \frac{2\,S}{T^2} = .17976$$

$$F = \frac{V}{T} = .16424$$

$$\overline{.49408}$$

Average, .16469

1 : 32 : : x : .16469. x = .0051465; per ton = .0051465 × 2,000 = 10.293 lbs., equals total resistance per ton, *if* resistance were constant. The grade for 1,000 ft. from north end of base line was, as before, .377 per 100 ft., and beyond that was level, as in 14.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine	36.6	1,000	36,600.0
Tender	23.4	1,020	23,868.0
30	23.8	1,052	25,037.6
29	24.7	1,084	26,774.8
28	25.5	1,116	28,458.0
27	25.6	1,148	29,388.8
26	24.5	1,180	26,160.0
25	24.2	1,200	
24	24.0	1,200	
23	24.6	1,200	
22	22.0	1,200	
21	21.0	1,200	283,200.0
20	23.5	1,200	
19	23.9	1,200	
18	23.9	1,200	
17	24.1	1,200	
16	21.8	1,200	
	420.1		479,787.2

479,787.2 × 7.54 (due gravity) 3,617,595.488

As before,

420.1 (tons) × 10.293 (est. resistance) × 1,982 .... 8,570,344.993

4,952,749.505

Divide by 1,982 (distance) 2,498,864

Divide by 420.1 (tons) .... 5.948 lbs.

resistance per ton other than gravity.

Experiment 16.—Same time, train and conditions as last. Light wind in front and right side.

Time passing base (200) .... 11.4 sec.
Speed per second .... 17.54 ft.
Speed per minute .... 1,052.6 "

Speed per hour .... 11.96 m.
Run .... 870 ft.
Time .... 103 sec.
" (estimated) .... 99 "

As before, $V = 17.54$ $S = 870$ $T = 103$.

$$F = \frac{V^2}{2S} = .17681$$

$$F = \frac{2\ S}{T^2} = .16401$$

$$F = \frac{V}{T} = .17029$$

.51111

Average, .17037

1 : 32 : : x : .17037. x = .005324 ; .005324 × 2,000 = 10.648 = estimated resistance if regularly applied.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine	36.6	870	
Tender	23.4	870	
30	23.8	870	
29	24.7	870	160,167.0
28	25.5	870	
27	25.6	870	
26	24.5	870	

Train	Tons	Distance on grade.	Tons × distance.
25	24.2	838	20,279.6
24	24.0	806	19,344.0
23	24.6	774	19,040.4
22	22.0	742	16,324.0
21	24.0	710	17,040.0
20	23.5	678	15,933.0
19	23.9	646	15,439.4
18	23.9	614	14,674.6
17	24.1	582	14,026.2
16	21.8	550	11,990.0
	420.1		324,258.2

324,258.2 × 7.54 (due gravity)............................2,444,906.828

As before,

420.1 (wt.) × 10.648 (est. resist.) × 870 (dist.).............. 3,891,705.576

Leaving a resistance other than gravity.................... 1,446,798.748

Divide by 870 (distance).. 1,662.987

Divide by 420.1 (tons).. 3.878 lbs.

equals resistance per ton other than due gravity.

Experiment 17.—Same train, time and conditions:

Time passing base...... 12.8 sec.

Speed per second....... 15.62 ft.

Speed per minute.......937.5 "

Speed per hour......... 10.05 m.

Run....................... 670 ft.

Time .... 93 sec.

" (estimated).......... 86 "

$V = 15.62 \qquad S = 670 \qquad T = 93.$

$$F = \frac{V^2}{2S} = .18207$$

$$F = \frac{2S}{T^2} = .15496$$

$$F = \frac{V}{T} = .16796$$

$$\overline{.50499}$$

Average, .16833

$1 : 32 :: x : .16833. \quad x = .00526$; $.00526 \times 2{,}000 = 10.52$ lbs. = estimated constant resistance.

Train.	Tons.	Dist. on grade.	Tons × distance.
Engine	36.6	670	
Tender	23.1	670	
30	23.8	670	
29	24.7	670	123,950.0
28	25.5	670	
27	25.6	670	
26	24.5	670	
25	24.2	638	15,439.6
24	24.0	606	14,544.0
23	24.6	574	14,120.4
22	22.0	542	11,924.0
21	24.0	510	12,240.0
20	23.5	478	11,233.0
19	23.9	446	10,659.4
18	23.9	414	9,894.6
17	24.1	382	9,206.2
16	21.8	350	7,630.0
	420.1		240,841.2

240,841.2 × 7.54 (due gravity)........................	1,815,912.648
As before,	
420.1 (tons) × 10.52 (est. resist.) × 670 (dist.)............	2,961,032.840
Resistance other than gravity........................	1,145,190.192
Divide by 670 (distance)........................	1,709.239
Divide by 420.1 (tons)........................	4.068 lbs.

resistance other than due gravity.

Experiment 18.—Same train, place and conditions. Wind as in last, about three miles or, perhaps, more per hour on right hand and well ahead.

Time passing base (200)....	25.6 sec.	Run........................	191 ft.
Speed per second..........	7.81 ft.	Time........................	53 sec.
Speed per minute..........	468.7 "	" estimated..........	49 "
Speed per hour..........	5.32 m.		

$V = 7.81 \qquad S = 191 \qquad T = 53$

$$F = \frac{V^2}{2S} = .1592$$

$$F = \frac{2S}{T^2} = .1360$$

$$F = V = .1474$$

$.4426$

Average, $.1475$

$1 : 32 :: x : .1475. \quad x = .0045 ; .0046 \times 2{,}000 = 9.22$ lbs. = estimated constant resistance.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine........................	36.6	191	
Tender........................	23.4	191	
30........................	23.8	191	
29........................	24.7	191	35,163.1
28........................	25.5	191	
27........................	25.6	191	
26........................	24.5	191	
25........................	24.2	159	3,847.8
24........................	24.0	127	3,048.0
23........................	24.6	95	2,337.0
22........................	22.0	63	1,386.0
21........................	24.0	31	744.0
20........................	23.5		
19........................	23.9		
18........................	23.9		
17........................	24.1		
16........................	24.8		
	420.1		46,525.9

46,525.9 × 7.54 (due gravity)........................	350,805.286
420.1 × 9.22 (est. resist.) × 191 (distance)........................	739,804.502
Resistance other than gravity........................	488,999.216
Divide by 191 (distance)........................	2,560.206
Divide by 420.1 (tons)........................	6.094 lbs.

resistance per ton other than gravity.

Experiment 19.—Same train, etc.

Wind a little stronger each time: three miles an hour at least.

Time passing base	26.6 sec.	Run	179 ft.
Speed per second	7.51 ft.	Time	51 sec.
Speed per minute	450.14 "	" (estimated)	49 "
Speed per hour	5.11 m.		

$V = 7.51 \qquad S = 179 \qquad T = 51.$

$$F = \frac{V^2}{2S} = .15754$$

$$F = \frac{2S}{T^2} = .13755$$

$$F = \frac{V}{T} = .14675$$

$$.44134$$

Average, .14711

1 : 32 : : x : .14711. x = .004597: .004597 x 2,000 = 9.094 lbs. = estimated resistance if constant.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine	36.6	179	
Tender	23.4	179	
30	23.8	179	
29	24.7	179	32,953.9
28	25.5	179	
27	25.6	179	
26	24.5	179	
25	24.2	147	3,557.4
24	24.0	115	2,760.0
23	24.6	83	2,041.8
22	22.0	51	1,122.0
21	24.0	19	456.0
20	23.5		
19	23.9		
18	23.9		
17	24.1		
16	21.8		
	420.1		42,891.1

42,891.1 × 7.54 (due gravity)	323,398.894
420.1 × 9.094 (est. resist.) × 179 (dist.)	683,849.703
	360450.809
Divide by 179 (dist.)	2,013.687
Divide by 420.1 (tons)	4.793 lbs

resistance other than due gravity per ton.

Experiment 20.—Same time, train, etc.

Time passing base	20.8 sec.	Run	305 ft.
Speed per second	9.61 ft.	Time	62 sec.
Speed per minute	577 "	" estimated	63 "
Speed per hour	6.56 m.		

$V = 9.61 \qquad S = 305 \qquad T = 62.$

$$F = \frac{V^2}{2S} = .151397$$

$$F = \frac{2S}{T^2} = .158688$$

$$F = \frac{V}{T} = .155000$$

$$.465085$$

Average, .155028

1 : 32 : : x : .155028. x = 9.689 lbs. estimated constant retarding power per ton.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine	36.6	305	
Tender	23.4	305	
30	23.8	305	
29	24.7	305	56,150.5
28	25.5	305	
27	25.6	305	
26	24.5	305	
25	24.2	273	6,606.0
24	24.0	241	5,784.0
23	24.6	219	5,387.4
22	22.0	187	4,114.0
21	24.0	155	3,720.0
20	23.5	123	2,890.5
19	23.9	91	2,174.9
18	23.9	59	1,410.1
17	24.1	27	650.7
16	21.8		....
	420.1		88,888.7

88,888.7 × 7.54 (due gravity).. 670,220 798

420.1 × 9.689 (estimated resistance) × 305 (distance).........1,241,456.414

Total resistance due other than gravity..................... 571,235.616

Divide by 305 (distance).. 1,872.903

Divide by 420.1 (tons)..4.458 lbs.

equals resistance per ton other than gravity.

Experiment 21.—Same train, time and conditions.

Time passing base	17.6 sec.	Run	405 ft.
Speed per sec.	11.37 ft.	Time	70 sec.
Speed per min.	662 "	" (estimated)	71 "
Speed per hour	7.73 m.		

$V = 11.37 \qquad S = 405 \qquad T = 70.$

$$F = \frac{V^2}{2S} = .1596$$

$$F = \frac{2S}{T^2} = .1653$$

$$F = \frac{V}{T} = .1624$$

.4873

Average, .16243

1 : 32 :: x : .16243. x = .005107; .005107 × 2,000 = 10.214 lbs. = estimated constant resistance per ton.

Train.	Tons.	Distance on grade.	Tons × distance.
Engine	36.6	405	
Tender	23.4	405	
30	23.8	405	
29	24.7	405	74,560.5
28	25.5	405	
27	25.6	405	
26	24.5	405	
25	24.2	373	9,026.6

Train.	Tons.	Distance on grade.	Tons × distance.
24	24.0	341	8,184.0
23	24.6	309	7,601.4
22	22.0	277	6,094.0
21	24.0	245	5,880.0
20	23.5	213	5,005.5
19	23.9	181	4,325.9
18	23.9	149	3,561.1
17	24.1	117	2,819.7
16	21.8	85	1,853.0
	420.1		128,911.7

128,911.7 × 7.54 (due gravity)	971,994.218
420.1 × 10.214 (est. resist.) × 405 (dist.)	1,737,815.067
Resistance other than gravity	765,820.849
Divide by 405 (distance)	1,644.002
Divide by 420.1 (tons)	3.913 lbs.

resistance per ton other than gravity.

Experiment 22.—Same train and conditions.

Time passing base	16.4 sec.	Run	415 ft.
Speed per second	12.2 ft.	Time	70.5 sec.
Speed per minute	732 "	" (estimated)	68 "
Speed per hour	8.3 m.		

$V = 12.2 \qquad S = 415 \qquad T = 70.5$

$$F = \frac{V^2}{2S} = .17932$$

$$F = \frac{2\,S}{T^2} = .16703$$

$$F = \frac{V}{T} = .17305$$

$$.51937$$

Average, .17312

1 : 32 :: x : 17312. $x = .00541$; .00541 × 2,000 = 10.83 lbs. = estimated constant resistance per ton.

Train.	Tons.	Dist. on grade.	Tons × distance.
Engine	36.6	415	
Tender	23.4	415	
30	23.8	415	
29	24.7	415	76,401.5
28	25.5	415	
27	26.6	415	
26	24.5	415	
25	24.2	383	9,268.6
24	24.0	351	8,424.0
23	24.6	319	7,847.4
22	22.0	287	6,314.0
21	24.0	255	6,120.0
20	23.5	223	5,240.5
19	23.9	191	4,564.9
18	23.9	159	3,800.1
17	24.1	127	3,060.7
16	21.8	95	2,071.0
	420.1		133,112.7

133,112.7 × 7.54 (due gravity)..........	1,003,669.758
420.1 × 10.82 (est. resist.) × 415 (dist.)....	1,886,375.030
Resistance other than gravity	883,705.272
Divide by 415 (distance).........	2,129.410
Divide by 420.1 (tons)......................	5.068 lbs.

resistance per ton other than due gravity.

SUMMARY OF EXPERIMENTS.

No.	Speed pr. hr.	Started on Grade.	Started on Curve	Run on Grade.	Run on Curve.	Distance.	Time.	Est. time.	Res due gravity	Other resist.
1	11.70	level.	....	52.8	....	538 ft.	.....	63 sec.	20 lbs.	5.98
2	9.43	"	... ...	"	...	403 "	......	58.3 "	"	6.45
3	6.81	"	... ...	"	....	234 "	.....	47 "	"	8.09
4	7.70	"	....	"	....	316 "	......	56 "	"	5.95
5	10.65	"	... ...	"	. ....	495 "	......	63 "	"	5.38
Av'ge.	9.25	....	.. ....	... ...	.. ...	397 ft.	.....	57.4 sec.	20 lbs	6.37
6	11.33	52.8	... ..	52.8	2°	321 "	.. . .	39 "	20 "	6.55

No.	Speed per hr.	Started on Gr'de	Started on Cr've	Run on Gr'de	Run on Cr've	Time. Actual.	Time. Est'd.	Dist. run.	Resistance. Gra'y	Resistance. Other	
8	12.08	Level	......	Level	......	. ...	116.5	1,500	......	5.19	rn'g at sp'd 5.52 end of 1,500 feet.
9	7.82	"	......	"	......	....	221	1,272	......	3.246	
10	6.73	"	....	"	......	185.5	205	1,013	......	3.346	
11	6.04	"	......	"	.. ..	132.5	133.5	592	.....	4.18	going south.
12	7.57	"	......	"	......	182.4	194.2	1,079	.....	3.81	
13	7.63	"	...	"	.	166.4	165.3	925	.....	4.20	" "
Av'g	7.98	......	.....	. ..	..	. ..	....	.....	.....	3.995	....
"	7.16	..	.. ..	.....		....	...	976	....	3.756	9 to 13
14	12.17		......	19.9	....	104	94.3	847	7.54	3.935	
15	16.63		.....	"	.....	148.5	121	1,982	"	5.948	
16	11.96		....	"	.....	103	99	870	"	3.878	
17	10.65		...	"	.....	93	86	670	"	4.068	
18	5.32	3-5 Ft	......	"	... .	53	49	191	"	6.094	
19	5.11	2-5up	...	"	......	51	49	179	"	4.793	
20	6.56	gr'de	.....	"	.....	62	63	305	"	4.458	
21	7.73	19.9	......	"	......	70	71	405	"	3.913	
22	8.30		......	"	......	70.5	68	415	"	5.068	
	9.38	......	.....	.....	......	83.8	......	651.6	7.54	4.684	Average.

8 to 22.... .... 4.408 Total.

Average all on straight line 1-5, 8-22.. ....4.898

No. 6 on two degrees curve.. ....6.55

A portion of the resistance other than gravity in these experiments was atmospheric resistance, partly due to speed of trains and partly due to wind.

In experiments 1 to 6 and 8 and 9 the wind was so light and so near right angles that its effect could hardly be estimated.

In 10 and 12 it was on the rear quarter, 30 or 40 degrees from the line of the train and about four miles per hour.

In the other experiments, when it is mentioned it was on the right hand, 30 to 40 degrees from dead ahead, and estimated about four miles per hour.

In order to make our estimates we will assume that the pressure per

square foot due speed is as laid down by various authorities and as given below:

Speed per hour.	Velocity per sec.	Pressure per sq. ft.
1	....	....
2	....	....
3	4.4	.044
4	5.87	.079
5	7.83	.123
6	8.8	.177
7	10.25	.241
8	11.75	.315
9	13.2	.400
10	14.67	.492
12	20.5	.964
15	22	1.107
16	23.45	1.25
18	26.4	1.55

The train consisted of an engine and fifteen coal cars, loaded as high as coal could well be piled on.

The surface presented by the engine we estimated to be about 64 square feet, and as the wind was at an angle, it took effect on the sides of the train as well as upon the ends of the cars which presented a surface, and the coal, and we estimated that the surface so acted on was about six square feet per car. This would make the whole surface 154 square feet, and upon this surface we have figured, although Mr. Chanute estimates that the additional surface for each car is about twenty per cent. of the first surface presented, or a little more than twice what we have taken. If he is right, results 67 per cent. greater than we show would be reached.

As we do not wish to *over*-estimate, we will assume our figures for 154 square feet for wind pressure.

The wind pressure varies as the square of the velocity; as our train moved from a given speed to a stand still we must average the effect, which would be as the average of the square of the various speeds during the time—which within the limits of our experiments would be substantially one-fourth less than half the maximum effect, or three-eighths of the maximum effect *i. e.*, maximum pressure. The variation from this is so small that it will make no practical difference in figures.

On this basis we figure as follows:

EXPERIMENT 1.

Pressure of wind	.0
" due maximum speed	.964 lbs.
Three-eighths of this	.362 "
154 sq. ft. × .362 lbs. pressure	55.748 lbs.
Divide by 420.1 tons (wt. of train)	.132 lbs.

resistance per ton due atmospheric causes.

[In the same way the writer gets the atmospheric resistance for each of the 21 experiments. It is not thought essential to print the calculations here.]

RESULTS TABULATED.

Series.	Experiments.	Resistance other than gravity.	Atmospheric resistance.	Friction and other resistance.
1	1	5.98	.182	5.848
	2	6.15	.062	6.388
	3	8.09	.091	8.009
	4	5.95	.030	5.920
	5	5.38	.090	5.290
Average				6.291
2	6	6.55	.110	6.440 on 2° curve
3	8	5.190	.204	4.986
	9	3.246	.044	3.202
	10	3.316	.002	3.314
	11	4.180	.056	4.124
	12	3.810	.026	3.784
	13	4.200	.069	4.131
Average				3.929
4	14	3.935	.163	3.772
	15	3.948	.215	3.733
	16	3.878	.162	3.716
	17	4.068	.130	3.938
	18	6.094	.049	6.045
	19	4.793	.047	4.746
	20	4.458	.059	4.399
	21	3.913	.070	3.843
	22	5.068	.079	4.989
Average				4.353
Average 8 to 22				4.183
1 to 5 and 8 to 22				4.710

TABLE SHOWING AOTUAL TIME, ESTIMATED TIME, INITIAL VELOCITY IN MILES PER HOUR AND FRICTIONAL RESISTANCES AS CALCULATED.

Series.	Exp.	Observed time.	Estimated time.	Initial speed.	Frictional resistance.
1	1	.....	63.	11.70	5.848
	2	.....	58.3	9.43	6.388
	3	.....	47.	6.81	8.309
	4	.....	56.	7.70	5.920
	5	.....	63.	10.65	5.290
2	6	.....	39.	11.33	6.440 2° curve
3	8	.....	116.5	12.08	4.986
	9	.....	221.	7.82	3.202
	10	185.5	205.	6.73	3.344
	11	132.5	133.5	6.04	4.124
	12	182.4	194.2	7.52	3.784
	13	166.4	165.3	7.63	4.131
4	14	104	94.3	12.17	3.772
	15	148.5	121	16.63	3.733
	16	103	99	11.96	3.716
	17	93	86	10.65	3.938
	18	53	49	5.32	6.045
	19	51	49	5.11	4.746
	20	62	63	6.56	4.399
	21	70	71	7.73	3.843
	22	70.5	68	8.30	4.989
Average				9.041	

From these figures we may conclude that the frictional resistance of

that train, including the engine, was 4.725 lbs. per ton, though many of the results are below this.

You will note that in five cases the estimated time taken in the stop was more than the actual, and in eight cases it was less.

You will note that the initial speed in cases where the estmated time exceeds the actual is low, averaging 6.72 miles; while in cases where the estimated time is less than the actual, the initial speed is higher, averaging 9.72 miles, or almost 45 per cent. higher.

Now in the first ten cases the average initial speed is on an average of 9.69 miles, and if the same rules hold we will have an estimated time of considerably *less* than the actual.

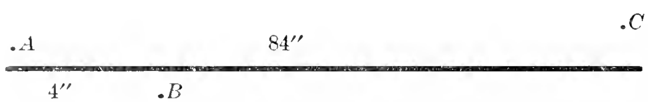
In the case of No. 12, we found that an increase of six per cent. of the estimated time over the actual would in calculation show a six per cent. decrease in the resistance.

If the time used in the calculation of cases 1 to 9 is too small, then the use of the actual or correct time in the calculation would show a resistance less than that tabulated by a percentage equal to the error in the time element.

How much of the resistances calculated is due to imperfect track is unknown. In no case was the track perfect, though it was fair, and an average sand-ballasted track.

Some very crude experiments were made to test the frictional resistance both at the start and when in motion, the cars used being of the lot used in former experiments, weight of which we had.

Our arrangement for measuring the resistance being a lever with length four inches and eighty-four inches, with spring balance to measure strain; thus:



This lever being upon one empty coal car at one end, the point A being fixed upon the car, the point B being upon a wire which was fastened to the draw-bar of the car to be tested; the point C being the point to which the spring balance was fixed, the other end of the balance being put to the lever.

We found that the arrangement was not accurate, as, for instance, the weight of the parts would show on the balance, and we had to start in by an allowance to provide against such influence. The pointer would bob about rapidly, so that an exact reading could hardly be taken. We attempted to read the amount that it took to start the car, and then how much to keep it going. We could not get an exactly steady motion, and the strains after the start were spasmodic in spite of all we could do.

The point selected was upon a level piece of track, on straight line, steel rail and good surface.

The first test was with car 2,057, weight 47,700 lbs.

We give first the number of the test; second, the amount our scale registered (after deducting our allowance) to start the car; third, the

range through which our pointer vibrated (after deducting as before) to keep the car going :

No. test.	Pointers when car started.	Range of pointers to keep moving.	No. test.	Pointers when car started.	Range of pointers to keep moving.
1	29	4–12	13	8	2–5
2	24	2–10	14	12	2–6
3	24	4–8	15	11	....
4	30	4–8	16	13	....
5	14	4–8	17	16	....
6	30	4–10	18	10	....
7	12	3–6	19	15	....
8	14	3–10	20	21	....
9	13	4–8	21	15	....
10	16	4–10	22	20	....
11	11	....	23	10	....
12	8	2–6			

Footing of experiment to start........ 355
Average........ 15.44
Multiply by the leverage, 21, and we have........ 324.24
Divide by 25.85 (tons)........ 13.595
which we may take as the resistance per ton upon this car at the start.
Foot the average of amounts required to keep the car in motion and we have........ 745
Which gives an average of........ 5.73
Multiply by 21 (leverage)........ 120.33
Divide by 23.85 (tons)........ 5.04
equals resistance per ton.

The wind was light and upon side, so did not affect it.

Another car was taken, weight 47,100 lbs. = 23.55 tons.

As before,

Test.	Start.	Range.	Test.	Start.	Range.
24	21	.....	35	19	.....
25	21	.....	36	26	.....
26	24	.....	37	28	.....
27	21	.....	38	30	.....
28	27	4–8	39	28	2–12
29	12	8–12	40	27	.....
30	8	4–8	41	28	.....
31	19	3–8	42	19	8–12
32	17	7–14	43	31	4–10
33	15	2–10	44	27	.....
34	14	6–14			
				462	78
Average				22	7.8

$22 \times 21 = 462$, divided by $23.55 = 19.62$ = average resistance per ton to starting.

$7.8 \times 21 = 163.8$, divided by $23.55 = 6.96$ = resistance when running very slowly.

Next car : weight, 50,700.

Test.	Start.	Range.	Test.	Start.	Range.
45	31	.....	48	34	4–12
46	28	4–10	49	30	3–6
47	26	2–6	50	31	3–8
				180	30
Average				30	6

30 × 21 (leverage) = 630, divided by 25.35 = 24 85, average resistance at start.

6 × 21 = 126, divided by 25.35 = 4.97 = resistance in motion.

The motion in last car was about three or three and a half miles per hour, while in other two it was very much less: just barely a motion.

The result as a whole was very unsatisfactory, and of little or no value, except to show that the frictional resistance from a start is much more than while in motion.

The average resistance to a start was 17.27 lbs. per ton, while that to keep in motion seems to have been about 5.10 lbs. per ton, or less than one-third of the former.

KNOXVILLE, Tenn., Nov. 5th, 1885.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

DECEMBER 1, 1885 :—The 219th meeting was held in the Society's Hall, at 7:30 P. M. Mr. Comstock was called to the chair.

Mr. Herr was appointed Secretary *pro tem.*

The minutes of the preceding meeting were read and approved.

Application for membership was presented from Mr. Charles Emery Billin, of Chicago, indorsed by Messrs. Cooley, Williams and MacRitchie.

The Committee on Civil Works under the United States Government presented circular letters from the Engineers' Club, of Cleveland, O., and St. Louis, Mo., in reference to the Convention of Delegates to be held at Cleveland, O., on the 3d, 4th and 5th inst. for consideration of the subject.

The Committee also reported that Prof. L. E. Cooley will represent this Society in the Convention.

A paper by Mr. C. H. Hudson, of Knoxville, Tenn., on Descriptive Experiments to Determine Frictional Resistance of Railway Trains was read by the Secretary. HIERO B. HERR, Secretary *pro tem.*

[*Adjourned.*]

At the next meeting, Tuesday, Jan. 5, 1886, the annual election for President, First Vice-President, Second Vice-President, Secretary, Treasurer, Librarian and Trustee, will take place.

Members expecting not to be present can send letter ballots.

Mr. Zellweger will present a paper in answer to Mr. Matlack's query as to disposition of house garbage in cities.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

OCTOBER 27, 1885 :—Special meeting held. President Holloway in the chair.

Minutes of last meeting were read and approved.

All of the Secretaries being absent, M. E Rawson was elected Secretary *pro tem.*

By request, Professor Eisenman stated that the object of the special meeting was to hear and consider the report of the special Committee appointed April 14, 1885, in relation to the proposed Convention of Civil Engineers, to be held in Cleveland, December 3, 4 and 5, 1885, to consider the relations between Civil and Military Engineers upon Civil Government Works. The Committee consists of Professor Eisenman, Chairman ; W. P. Rice, J. J. Laman, Wm. T. Blunt and James Ritchie. The report of Mr. Blunt, Secretary of the Committee, was read and ordered filed. As suggested in said report, the chair appointed a committee of five, consisting of Messrs. Holloway, Whitelaw, Searles, Dunham and Jones, to report at next meeting, upon the matter of entertainment of visitors to the proposed convention.

On motion, Mr. Eisenman's committee was authorized to procure badges for

delegates, visitors and committees attending the Convention, the cost not to exceed ten dollars.

The report stated that reports had been received from twenty-five of the twenty-eight organizations addressed, and that only two had declined to co-operate in the movement. The Committee submitted copies of printed reports to be sent out, setting forth the date and object of the Convention.

The matter was discussed at length by Messrs. Eisenman, Searles, and others. M. E. RAWSON, Secretary *pro tem.*

[*Adjourned.*]

NOVEMBER 10, 1885:—Regular meeting held. In the absence of both President and Vice-President, E. H. Jones was elected President *pro tem.*

Minutes of the last meeting were read and approved.

The Committee to whom was referred the question of entertainment of delegates to the Engineers' Convention, to be held December 3, 4 and 5, reported. The whole matter of entertainment was recommitted to the Committee with power to act.

On motion, the Committee was requested to send notices to all the members to ascertain the number who would attend the entertainment.

The following resolution by Mr. Paul was adopted:

Resolved, That the services of a stenographer be secured for one evening, on trial, to report the proceedings of the Club, especially the discussions following the papers, such report to be revised by the Committee on Publication before being printed in the Proceedings. On motion of Mr. Mordecai, the Recording Secretary was authorized to employ such stenographer.

Mr. N. B. Wood gave a short talk upon the subject of natural gas, which was freely discussed by the members Mr. Wood was requested to present a paper on the subject.

A map was received from Mr. Gratz Mordecai showing New York harbor.

[*Adjourned.*] M. W. KINGSLEY, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. January, 1886. No. 3.

A RATIONAL POLICY OF PUBLIC WORKS.

BY L. E. COOLEY, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS; PRESIDENT CIVIL ENGINEERS' COMMITTEE ON NATIONAL PUBLIC WORKS.

[Read January 5, 1886.]

[The theory of the argument is, that the utility of a system of public works must be apparent, in order to furnish a sound reason for providing a special service, or a change in the present service, for its conduct. In giving prominence to interior improvements, it is assumed that there is no difference of opinion as to the great importance of coast works.]

INTRODUCTION.

Is there need of better provision for a system of internal improvements?

If so, what action should be advised for determining a rational policy and providing a service for carrying it out?

To base the consideration of this question solely on the public weal, is to promote the highest justice to all interests.

If the utility of a system of internal improvements be admitted, the importance of a specially organized service is self-evident. If Congress is prepared to adopt a consistent and uniform policy toward public works, it is ready to provide an adequate service for their charge. That the time has come for the definite inauguration of such a policy may not be sufficiently clear to gain the general consent of our legislators. Meantime, local interests which can influence votes will dictate appropriations, and perhaps secure special commissions and appointees thereon. Congress, as hitherto with all irregular appropriations, will continue to assign their expenditure to some one of the great departments which may be provided with a bureau more or less well adapted for their disbursement.

To promote a change to a rational policy from the present wasteful and unfruitful system, if indeed it may be called a system, is the duty of a profession which can most clearly understand its deficiencies.

Any intermediate steps that might be taken would seem to afford greater possibilities for evil than the condition it is sought to remedy. To see any necessity for change is to recognize the whole truth: to urge its full conclusion is likely soonest to attain a desirable consummation, free from the suspicion of personal or class interests. Accepting these premises for the time being, the reasons for a policy different from that now prevailing are in order.

THE UTILITY OF A PUBLIC WORKS SYSTEM.

Competition by Water.—Lake craft from Chicago or Milwaukee to Buffalo or Erie, receive from one-third to one-fourth the through rate by lake and rail to the sea-board :* or the lake rate per ton-mile is one-fourth to one-sixth the rail rate. If these rates may be assumed to represent relative cost of transportation, then it is simply a question of how far the size of boats may be reduced, how much their speed shall be lessened, or what difficulties of navigation are to be contended with, to bring the cost of water carriage up to that of rail. The margin is certainly ample to admit great possibilities in a well-considered waterway system.†

Commissioner Fink, of the Trunk Line pool, has stated that the Erie Canal influences rail rates to the seaboard as far west as St. Louis and south to the Ohio River. The Illinois and Michigan Canal, of less adequate proportions and with limited commerce, favors all the towns along its route with a rail rate much less than that of towns distant a day's journey by wagon.‡

The lines of boats on the upper Mississippi give great advantage in north and south rail rates to the cities along its course, and even the occasional boat which once or twice in a season may reach a Missouri, river town, mitigates the railway tariff. The few months of intermittent navigation on the Ohio are profitably utilized by coal fleets, heavy products and even merchandise, and the lower Mississippi exercises an influence quite out of proportion to southward-bound commerce.§

Our waterways, undeveloped and unimproved and of inadequate capacity, in fragmentary systems and closed for a part of each year, frequently not in the direction of traffic requirements, afford their bordering towns cheaper rates and indirectly benefit the whole country.‖ It was repeatedly admitted by railway officials before the Interstate Commerce Committee of the U. S. Senate, the past summer, that the water route, though it may not carry a pound of freight, exercises a *moral* influence over rail rates. A channel that can be navigated is a

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*Statement by S. S. Merrill, manager of a line of lake boats, before the U. S. Senate Committee on Interstate Commerce, at the Chicago session, the past summer. The lake route is practically twice the rail distance by five different lines from Erie or Buffalo to the seaboard. Lake rates on coal from lower ports, less than one-third that to the Mississippi, for five times the distance.

†Previous to 1858, but 9½ feet could be carried through Lake St. Clair; 12 or 13 feet up to 1874, and 16 feet since. Present plans contemplate an ultimate depth of 20 feet for lake navigation. The great reduction in lake rates following increased draft and improvements in vessels and machinery, may be expected to continue beyond all hope of rail competition, when enormous capital accounts and fixed charges are considered.

‡The railway commissioners' rate on wheat, generally adhered to at non-competitive points, is 7.2 cents per bushel for 130 miles. The rail rate from Henry to Chicago, 130 miles, is the same as canal rate, namely, 3 cents per bushel.

§The influence of the Mississippi river on rates to Atlantic ports, especially from St. Louis, is discussed in the reports on Internal Commerce of the United States, by Joseph Nimmo, Jr., Chief of the Bureau of Statistics, Treasury Department. See Report for 1880, *et seq.* Also papers by Fink and other authorities.

‖The far-reaching effect of competition is shown by Commissioner Vining of the Western Trunk Line Association. See *Railway Review*, Oct. 18, 1884 : "Necessity for a Classification of Freight."

latent force which becomes active when rates are pushed above a certain minimum.* If this be now true, what benefits may not be anticipated from the development of an adequate system, fully navigable at all times in the South, and, when not closed by ice, in the North?

France has, perhaps, a more fully developed waterway system than any other country, having expended $218,000,000 on 7069 miles of interior or non-maritime lines.† Within the past few years, she has been improving rivers of a class, at present, quite unworthy of attention here. Although rigidly controlling her railways, of which she becomes the owner after a limited time, she has recently given renewed attention to her waterways with a view to their fullest development in accordance with the latest studies; $270,000,000 have been set aside for the purpose by her government and her municipalities, and this for a territory considerably less than the combined area of Illinois, Iowa, Wisconsin and Minnesota. Under the circumstance of full control and ultimate ownership of all highways of commerce, this may be taken as the unbiased judgment of her statesmen and engineers. How puny seems the river and harbor bill for a country like the United States!

Manchester, England, has recently concluded to bring the sea to her doors through a canal thirty-five miles long, to cost $40,000,000. The maximum rates are fixed at one-half the present rates by rail or canal from Liverpool.‡

It would be a work of supererogation to cite further proof that water carriage in proper channels is the cheapest method of transportation. Was it not Lord Dundreary who noticed that all the great rivers ran by the big cities?

The Future System.—It requires but a superficial examination of our country to appreciate its possibilities in a magnificent public works system. Fringed about by a deeply indented coast, harbors in profusion invite fuller development. Great lakes and rivers, extending remotely from market points, drain basins unexampled in mineral and agricultural resources. Natural channels, susceptible of improvement to ample capacity, are well distributed. Topographical features favor the linking of the river systems to each other, to the lakes and to the seaboard.

The canal systems of our fathers are of the past, and the day of meagre channels and small boats is drawing to a close. The railway is better adapted to the quick, detailed and distributive traffic of our country. Natural channel-ways, developed to a capacity suited to fleets and boats of large burden, so articulated at vantage points as to require no change of cargo—a great trunk system with tributary water-ways of indefinite extent, joining market points of heavy traffic origin and destination—this is the system of the future.§

* "They can only increase their charges over the charges made by water routes to the extent that they offer additional advantages; while somewhat higher rates can be charged by the railroads, the basis of their charges are the charges made by water lines."—Albert Fink, Sept. 17, 1883, before the U. S. Senate Committee on Labor and Education. Virtually the Chicago and St. Louis rates by water are the basis to which the rail rates of the country are adjusted.

† New lines authorized, 1813 miles.

‡ Depth, 26 ft.; lockage, 60½ ft.; locks, 550 ft. by 60 ft.

§ Of what use are rivers? "To feed navigable canals," said James Brindley, the father of English canal engineering, more than a century ago. This remark, in a

It has been stated that the Mississippi Valley, comprising about one-third the territory of the United States, contains 15,000 miles of navigable streams; *i.e.*, streams which have been navigated and legally known as navigable. The question was investigated in 1881.* Taking the main river to Cairo and the basins of the Ohio, the Upper Mississippi and the Missouri, 10,000 miles of rivers were found, the projects for which considered an improvement feasible, at reasonable cost, for boats of a large class. This estimate omitted the tributaries of the lower river and a great number of minor streams for which appropriations have been made. On the same basis, the natural channels of the balance of our territory would readily raise the estimate to 20,000 miles. To make the system as complete as in France, by embracing minor streams and more expensive improvements, would give a mileage of not less than 50,000. To-day, 10,000 miles of improved channels would constitute a primary trunk system, about one-twelfth of the railway mileage, which would directly or indirectly regulate traffic charges throughout the country. Increasing density of population, traffic grown heavier and more concentrated, and the margin of profit on industry growing smaller, would gradually deman . extensions of the system until developed to its limit of usefulness.

Waterways as at present existing, in detached lengths, unsutied to economical transport, unavailable a good portion of each year, cannot be expected to attain great results and yet their influence is admitted. Waterways should constitute connected systems as well as railways, and they should be so planned as to avoid transshipment as much as possible. The same capacity cannot everywhere be provided, but improvements can be based on a few well considered types, uniform throughout the country, in lieu of present methods by detached works without reference to other works with which they will sometime constitute a system.

What can be Afforded.—Our territory extends so widely as to make the traffic tax between the producer and the consumer, the agriculturist and the manufacturer, the in erior and the seaboard, a heavy burden. The amount by which this burden can be lightened is the measure of what can be afforded for internal improvements.

The National Government, from 1790 to 1879, expended on all our rivers and harbors, $81,747,604.45.†

measure true at the time, became the chief dogma of canal engineers. The practice of this branch of the profession soon became fixed, and has shown little elasticity or advance under the changing requirements of th age, or the revolution wrought by the introduction of steam. Even as late as 1848, the Illinois & Michigan Canal, with meagre prism, was completed for horse boats alongside a river unusually well adapted to slack-water improvement for steamboats of a large class. The locks and dams on the lower Illinois is another case of reversion. Had dogma given way to wise forethought, the same expenditure could have resulted in a magnificent navigable channel from the Lakes to the Mississippi, and made of the Upper Illinois the Merrimack of the West.

* "Proceedings of the Missouri River Improvement Convention," (p. 59), St. Joseph, Mo., 1881; also, "A Plea for the Missouri River Improvement," by L. E. Cooley and S. H. Yonge, published by the City of Leavenworth, Kansas, 1884.

† Four bills have been passed since, aggregating $53,813,235; and $4,250,000 has been paid on the South Pass jetty improvement. A partial list of the work done on rivers and harbors, and such canals as have been turned over to the general government, by States, corporations and private individuals, up to 1879, aggregates an expenditure of $31,021,423.32. In aid of such work, the government has granted 3,057,840 acres of the public domain.

The State of New York, up to 1873, had expended on her canal system an equal amount, or $81,577,993; and received therefrom in tolls, up to 1876, $128,067,030; while the surplus earnings on the Erie Canal alone, up to 1873, above cost, operating expenses and maintenance, were $40,175,594.* The indirect benefits to New York and to the whole country have been immeasureable.

At the end of 1884, the railways of the United States aggregated 125,150 miles, with a share capital and indebtedness of $7,676,399,054, or $61,400 per mile, and on this sum it endeavored to collect dividends. Although the year 1884 was one of unusual depression, the gross earnings amounted to $770,684,908, and the net earnings to $268,106,258, or $2,142.28 per mile. The average rate was 1.236 cents per ton-mile.

It is not proposed to argue any abstruse questions in political economy. It is evident that if a system of public works could have saved to the people 10 per cent. of the gross earnings in 1884, and this ratio of saving could be maintained by its construction, an expenditure of over $2,500,000,000 at 3 per cent. could be afforded for its development. If far better results are to be realized, then by that much would the general public benefit in a clear gain. The railways would still retain traffic ample for a reasonable return on their *fair cost*, for all lines judiciously located and properly constructed. In the greater prosperity that would ensue, an increase in that traffic for which the railway is best adapted would doubtless provide better returns. While it might not be expected that waterways would promote the construction of railways and enhance their value, such has been the result throughout the Mississippi Valley, and from the great lakes eastward.

It is impossible to infer to what degree of perfection $2,500,000,000 could bring a public works system. This much is certain, however, that Congress cannot expect to attain great results with the expenditures of 90 years, an amount less than the aid to the Pacific railways in their brief history.† A well defined policy, a fully studied scheme and annual appropriation reasonable in view of the purposes to be subserved, would gradually bring relief in reduced cost of transportation.

The value of navigable channels is gradually impressing itself on the people. Along lines of heavy traffic their cheapness is admitted. As a bulwark against extortionate rates even before demanded by traffic, they secure recognition. Every steamboat and ship owner is a free competitor for traffic, thus adjusting profits to those of general business. A traffic charge is a tax which it is the function of government to lighten as much as may be possible.

If the claims for an interior system do not receive full assent, our coast and lake harbors of themselves can demand better provision. The increased draught of lake and ocean vessels makes deep entrances to our harbors imperative. Every port on our 20,000 miles of coast line requires

* Cost, including that of the original canal, extraordinary repairs and improvements up to 1876, $49,160,986.93. The free canal system went into effect at the beginning of 1883.

† The subsidy to the Pacific railways was $64,623,572. The principal and accrued interest, June 30, 1884, was $102,934,794.08. About 150,000,000 acres of land have been granted and about 50,000,000 patented or earned. It is reported that 100,000,000 may be forfeited at the will of Congress.

the watchful care and skill of the best service that can be provided. Many of these ports are at the outlets of great arterial systems which may carry the products of a nation to the seaboard, on its way to domestic or foreign markets; and they are likewise the natural entrepots through which the products of other lands may reach the great interior.

Can the growing sentiment of our people for interior and coast improvements, which is constantly breaking out in popular conventions and crude enactments in our legislative chambers, be indefinitely ignored?

THE GROWTH OF PRESENT METHODS.

A National Policy.—The policy of the General Government for the first half century of its existence was foreign to the construction and improvement of waterways and harbors, although the construction of national roads was largely entered upon. Notwithstanding the efforts of several of the States, notably New York in 1811, to induce Congress to undertake public works or to give aid, congressional action was limited to an occasional land grant for state enterprises, a practice that only grew to full fruition in the building of the land grant railways by private corporations. Accepting the policy of the General Government, the several States largely entered upon the construction of canal systems and even the improvement of rivers and harbors.

In this early day, the constitutionality of public works construction by the United States, except as warranted by military necessity, was gravely argued, and is even now brought forward in relation to special schemes. The military necessity plea served some earlier projects and again came to the front at the close of the civil war.

Under the commerce clause of the constitution, the Supreme Court has defined as navigable waters of the United States, those that "form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other States or foreign countries in the customary modes in which such commerce is conducted by water." Although the earlier decisions run back fifty years, it is only since 1870* that the limits and powers of the General Government have been well defined, and even now there are many points undecided. The paramount jurisdiction of the General Government is assumed in recent river and harbor bills and bridge laws, and of late States have recognized their subordinate powers on domestic streams and in bridging navigable waters. The construction of artificial channels around obstructions has been for some years accepted as proper, and as links between natural systems they are obtaining similar recognition. In fact, it may be doubted if there is any limit to the powers of Congress to provide commercial highways in the interests of commerce.

The history of our waterways ascribes to them remarkable pros-

* Sup. Ct. Decisions, 1870: "The Daniel Ball." The Grand River was declared to be a navigable stream and not a "domestic stream" solely under the jurisdiction of Michigan. The first important case was in regard to an exclusive franchise granted to R. R. Livingston and Robert Fulton for the navigation of the waters of the State of New York by boats moved by fire and steam. The doctrine was more fully defined in Gilman *vs.* Philadelphia and in the Wheeling bridge case, as also in the Rock Island bridge case.

perity until the advent of the railway systems, and as pioneers in the first development of the country. During the speculative and constructive period, with the large profits and rapidly changing values incident to the inhabitation of new territory, the railway, even with heavy traffic charges, proved its adaptation, and the waterways gradually fell into disuse. With the development of market centres, furnishing a cargo or bulk traffic in place of the old coasting trade, with a settled and dense population and fixed industries, with lower margins of profits on which freight charges most seriously infringed, waterways have taken on new life, and their improvement is loudly called for. With the long-recognized importance of coast harbors, this call is coextensive with our land.

The history of this question passes from a period when internal improvements were regarded as the peculiar function of the States, up through a marvelous development of transportation facilities by corporate capital, in which commerce has become a mighty problem of interstate concern, until a public works system is recognized as the province of the General Government That the growth of this idea will in time find expression in proper legislation, no one can doubt. That it should, ere this, have resulted in a well-defined policy, is the belief of students of the subject.

Legislation.—Our public improvements have secured appropriations most largely through local and sectional influences. Great popular conventions are held to express to Congress the earnest desire of the people for improved waterways and harbors. In these conventions diverse interests often strive for expression, and even in Congress they not infrequently so antagonize each other as to defeat legislation of great public moment. The limits hitherto set for the river and harbor bill, the great number of projects demanding attention, and necessarily included, have resulted in the arbitrary scaling of estimates to a fraction of what is required in individual cases to prosecute work economically or to even achieve success.

That improvements should be local and diverse, is to be expected. That there should be a medley of bridge laws, or none at all in some instances, is not strange. That even in connected or adjacent navigations, forming parts of a local system, there should be such diversity in permanent structures as to call for different classes of boats, is a legitimate result of present methods. That works should be undertaken which are totally separated from continuous navigable waters, or that expenditures should be made only remotely connected with the interests of navigation, need not be a matter of surprise. Do we wonder that the river and harbor bill should fall into disrepute, and the true friends of a public works policy pray that it may be killed annually until more rational methods can prevail?

The only effort which has been made to lay out a system of improvements was by the Windom Senate Committee of 1874. Although much interesting information was collected and some general recommendations of value made, no great result could be achieved by such a body, or by any body, in a brief space.

The study of internal improvements, and their execution, is the proper work of an organization constituted for that purpose. The local or sec-

tional scheme should go directly to this department for examination and reach our legislative halls only as a project in harmony with a general plan. Finally, in the elaboration of a general plan, we may suppose all local or sectional interests to have been properly consulted. By such methods, and appropriations commensurate with the purposes in view, will our public works assume a proper dignity.

Professional Organization.—With the growth of public improvements, the Military Engineer Corps is found in a neutral and powerless position. Originally, appropriations for works of military necessity, for roads or for explorations, were naturally delegated to the Secretary of War. That their disbursement should have been assigned to the Engineer Corps of the Army, even had other talent been then available, was proper, and the usage has continued to this time, although the purpose has largely changed. Except by custom and implication, Army engineers have no legal or legislative status for civil work, and may be considered as virtually on detached duty. Without proper status, they are powerless to devise or recommend a system. Even an opinion, in accordance with military ethics, may be impertinent, and wise enactments must take the chance of discovery by men unfamiliar with the requirements. Without tenure in the work to which Army engineers are assigned, they certainly cannot provide a status for their civil employés.

Such conditions, not generally understood, have naturally resulted in dissatisfaction, and it is not strange that under the spur of special interests, a remedy should have been discovered in the commission panacea. The apparent advantage to one section through a commission, leads to a struggle for like advantage elsewhere, until every large sectional interest may be expected to insist on its commission. This leads to a gradual disintegration of responsibility. Appointments become a matter of influence, with no assurance of training or skill for the work, and the tendency is inevitable to self-seeking and political control.

Although commissions, *per se*, may have been a benefit to our public works in mooted questions and special installations, yet, thereby, an organization has not been provided for their better conduct, nor has a desirable tendency been inaugurated. It has gone too far, however, to warrant no action or a return to the old regimen, and it should be wisely met by comprehensive legislation.

It is certain that any organization thus far constituted is quite unsuited to the requirements. Until, however, Congress defines a policy toward public works, a special organization can have little reason for existing.

THE DEFICIENCIES OF THE PRESENT ORGANIZATION.

To present without bias the deficiencies of the present river and harbor service is no light or enviable task. The organization of the Engineer Bureau is purely military, and solely as an arm of the military establishment is its policy defined. It has no proper legislative sanction for civil work, this being in the nature of a detached service by assignment of the Secretary of War, originally to works of military necessity. Adequate training and experience is not demanded for important civil duties, and officers are transferred from time to time with too little regard for the interests in which they are enjoyed. It cannot well be other-

wise where all duty must be subordinated to the military requirement. All laws, regulations and rulings are essentially military. How ill adapted they may be to the requirements of civil work, is chiefly known to those who have had experience under them. Regulations in regard to purchases, contracts, property; in regard to vouchers and reports of all kinds, are elaborately annoying, greatly increasing the cost of supervision, often tying the hands of the resident engineer or even defeating success in work requiring dispatch. A set of regulations based on the field requirements of civil work would promote sound business methods, but this is clearly impracticable until the whole matter is formally delegated.

The Corps of Engineers, U. S. A., at present comprises 112 members: of these, 35 are engaged in strictly military duty, 51 in strictly civil duty, while the balance have both military and civil duties. If the assignments be followed up in detail, it is found that with few exceptions, officers attain the rank of captain before assignment to civil work: in other words, that five or six years of post-graduate study and experience is regarded as essential to the completion of their military training.

For their civil work, no special course of study, preparation, experience or aptitude, is made a pre-requisite; yet no capable engineer officer will say that his problems of civil engineering taxed him less, or were less difficult, than those of his military experience.

The first civil assignment is usually as assistant to an officer of experience. As preparation for actual charge has not been made, the duties performed are generally nominal. Thanks, however, to an excellent training, experience in time may remedy deficiencies, though the lack of detail knowledge of field practice and construction may be sufficiently apparent.

Each district officer is directly responsible to the Chief of Engineers only, who, with divided duties, is supposed to consider and approve every project in the United States. The relief afforded by an occasional board is not a comprehensive one, and, practically, there is no inspection service. The corps boasts many civil engineers of high attainment, and that any success should be reached under a lack of proper method, is gratifying evidence of what might result from a definitive policy.

"Military and civil methods of administration are entirely diverse, and proceed upon diametrically opposed theories. The military officer plans and commands; the civil officer hears, weighs and decides."* That ideas are sometimes outranked in boards of military engineers, is the evidence of junior members. In like manner, may the subordinate service fail of a true development.

It has been remarked that the man of engineering habits of thought is a poor field officer.† If so, how far is a military training adapted to making the best civil engineer? One thing is certain, that the student

* Major J. W. Powell, Director of the U. S. Geological Survey, before a joint committee of the two houses of Congress.

† Another phase is illustrated in a recent remark of Adj. General Drum, in regard to the value of an experience in civil life, as evidenced by the great leaders which the late war brought to the front. He might also have cited the records of army and navy officers who have served in the Coast Survey.

who has mastered his course in a good engineering school and had five or six years' experience as assistant under a competent chief and in commercial methods, has fuller qualifications than the officer, who comes to his work after his post-graduate military service, a novice except in ability to organize. This of itself is a full argument for more rational methods.

Perhaps the most serious defect of our Corps of Engineers as an organization for civil work lies in the fact that responsible position is attained by transfer from a service of little similarity, and without antecedent training and experience; while the great body of whom technical knowledge and skill are required, perhaps equally competent, certainly with special training and years of experience, is ineligible. This class of men, under the general title of civil assistants, outnumber the officers from three to six times. Their employment is of course temporary, depending on the annual appropriation bill. However competent or ambitious to make this specialty a life work, they are confronted by uncertain tenure of position and ineligibility for responsible charge. In fact, have we not the anomaly of a service in which, as a general thing, the superior or responsible officers are unfamiliar with the field duties which they are called upon to direct and supervise? Does not this reverse the logic and the method of all human experience?

This condition cannot result in the best service. The time of the civil assistant on government work does not average three years, or in other words, when some competence in a difficult specialty is attained at government expense, it is immediately thrown away. The best talent of course will not remain without hope of future reward, and ever in the face of the growing conviction that the special experience acquired can avail little in other pursuits. It is not strange, therefore, that a large proportion of our best technical graduates should enter a service to find out their mistake, and resign with more or less resentment toward a condition of affairs in which all concerned are alike powerless to remedy.

The deficiencies of the service grow out of legislative inadvertence and military point of view. It is no plea of justice to the civilian, that could, of itself, demand a change. There is but one question, and that is—what is most expedient, or what will secure the best result? All that can be insisted upon is, that the present plan, or rather no plan, for it has grown like Topsy, is most ill adapted, and that a well considered change is demanded in the interest of a better service. All familiar with the matter recognize this, and it remains to define its character.

SUGGESTIONS FOR A SPECIAL ORGANIZATION.

The wise man is ready to rebuild when he tears down. Unless a well digested system can be substituted, to argue a change is folly. The interests concerned are far too important for other than grave deliberation and conservative methods. If we have not faith that Congress, recognizing the advisability of change, will order wisely, then far better to have left our efforts undone, unless, indeed, they should ameliorate somewhat the inevitable.

A cursory study of our river systems, lakes and coasts, suggests the

outline of an organization adapted to the requirements. The country naturally segregates into several grand divisions or departments, within each of which there is such similarity in physical features, such community of interests, as to demand related works or plans in mutual harmony. These grand divisions subdivide into districts of less individuality, but integral members of the group which constitutes the department. Adjacent departments will have much to consider in common, much to harmonize in the general development of trunk lines and the fixing of standard requirements for improvements of similar capacity.

Let the district be taken as the unit, with an officer in charge, and an organization competent for the multifarious duties involved in the design and execution of work. The several district officers may constitute a board, charged with the common interests and general plans for the department. Its chief should have no special charge, but should act as executive officer of the board. The several department chiefs may constitute a central board for the consideration of wider interests and the supervision and development of the public works system as a whole.

Within the district, resident engineers and assistants must be provided, down to the lowest grade requiring technical training, skill and ability. Starting with this grade, which may be one of probation, promotion should be step by step in accordance with a well-advised plan, preserving, however, elasticity enough to utilize the best thought in the profession. Such a system would not be unlike that of Prussia, in which all officials are educated and trained for their work as civil engineers.

Having decided upon a policy and the character of an organization, it is evident that to create it *de novo* and develop it to full efficiency, is a work of years. It is a truth that many engineers too little appreciate that river and harbor work is pre-eminently a specialty, requiring a high order of analytical ability, executive capacity and skill, to cope with active forces of destruction. The judgment acquired by special experience is not to be lightly thrown away.

As before stated, less than one-half the Engineer Corps is at present required for military duty, although the prospective and necessary work on our sea-coast defenses may soon demand quite its entire services. So there is now available over one-half the Engineer Corps as the nucleus of a civil establishment; and, with such civil assistants as may have developed special fitness, a fair working organization could be provided at once. It would be a matter of three or four years only before the new organization had become a consolidated, well-adjusted, living force, utilizing all the available experience and gradually establishing itself on a civil basis.

The organizing ability possessed by many of our engineer officers would be of the greatest service in the earlier stages of the new establishment. With the law intelligently framed and its provisions carefully worked out, the execution could not be left to more willing or appreciative hands; and doubtless many of attainment in civil work would elect permanent appointments in the new service. The deficiencies of our present no-system are too well recognized by those concerned, not to make a wise remedy devoutly to be wished. Thinking men will not resist a change

which assures better results, provided their vested interests are in some manner conserved.

WHAT SHOULD BE RECOMMENDED?

If the various phases of this subject have been clearly presented, then it is apparent that there has been a gradual change in attitude on the part of the United States toward internal improvements; that the time is approaching, if not already here, when the formal adoption of a well-considered policy will be necessary; that hitherto, appropriations have been irregularly made, largely through the influence of local or sectional interests and without a general purpose; that their expenditure has been delegated, like all irregular appropriations, to one of the departments for disbursement; that this disbursement has been assigned to a military bureau, not organized for civil work, and having no legislative status therefor; that this has not, and cannot, for reasons not generally understood, be satisfactory; that various interests have inaugurated the idea of commissions which, however well adapted to particular purposes, tend to an undesirable end; and that action should be taken looking to a rational policy and the provision of a special organization for its execution.

The general character of an organization which would seem to be adapted to the requirements of our great territory has been outlined, and ideas advanced as to the best method of attaining its consummation. It has been shown how all projects may be presented in accordance with a well advised plan, thus doing away with the unseemly strife of section, locality and district, and how great results may be attained for the common weal through a system of public improvements. While it is our privilege and duty as citizens to discuss these matters, having ireached our conclusions, it is incumbent upon us as professional men to point out the road to a solution.

It is evident that the consideration of this subject involves many complex questions. The work which is to be performed must be well understood. An organization which will secure the highest professional results and be in harmony with the genius of our institutions must be provided, and the legislation adapted to its needs well outlined. When the main requirements have been studied, experience abroad, so far as it may have a bearing, should be considered, and conclusions so matured as to eliminate purely individual opinion.

It is believed that the whole matter is in such shape as to make it impracticable to attain a definite system by a gradual change, or a species of growth. It will require time to bring those concerned to a full realization of the state of affairs and to an agreement as to a wise course to follow. To fly from the evils we have to those we know not of, can be ill afforded.

Therefore, it would seem wise of Congress to provide a board of Army and Civil Engineers, acquainted with this matter and realizing the necessity for a change, to consider the whole question of legislation and organization. Such a board could collate all the thought pertinent to the subject, and present its conclusions with recommendations for the consideration of Congress.

As engineers, we would feel confident that the subject would be handled as wisely as could be provided for, and that, for a purely professional organization, Congress would give heed to the conclusions.

SUGGESTIONS FOR A "DEPARTMENT OF PUBLIC WORKS."

The executive departments of the government present a curious medley of bureaus designed for sundry and various useful and special purposes. Of the seven great departments, three, those of State, Justice and the Post-Office, confine themselves strictly to their special work. The Navy Department indulges in occasional canal surveying. The War Department takes upon itself Meteorology, Geographical and Geodetic surveys and Internal Improvements. The Treasury has a Light-House establishment, a Coast and Geodetic survey, a Public Buildings bureau, a Marine Hospital service, a Bureau of Statistics, a Steamboat Inspection service, a Life Saving service, a Revenue Marine, etc. The Interior has a Fish Commission, Geological surveys, Patents, Land surveys, Pensions, Indian Affairs, Census, Pacific Railway Commission, Capitol Building, etc.

It is apparent that the majority of these assignments are utterly incongruous. They have frequently come about through the recommendation of cabinet officers, under the initiative of some ambitious and stirring subordinate. Some of these bureaus are misplaced or in the wrong department and could be transferred with good results, while other departments should be confined strictly to the work for which they were organized. Why the Treasury should concern itself with other matters than those of finance, or the Navy and War Departments indulge in work foreign to their purpose, is anomalous. The special bureaus cannot assimilate the general service of the departments. It is not easy to provide the special organization, rules and supervision, which may be required.* These bureaus become, in nature, petty, semi-independent satrapies.

That it would be wise to segregate all our technical bureaus, or those requiring scientific and constructive skill, from their present unrelated departments, and aggregate them in a department by themselves, cannot be seriously questioned. Harmony in organization, regulations well adapted to the work, proper supervision, and the interchange of special experience, would all be promoted. Such a department would have its various purely scientific bureaus, its bureau of surveys, of architecture, of internal improvements, etc., all based on such a thorough civil service as must result where technical attainment is uniformly required.

Some of the bureaus referred to have been the subject of agitation with a view to better or more rational methods. Sooner or later all these interests must centre about the common idea of a department.

The adoption of a consistent policy toward our public works and the provision of an organization especially adapted to their requirements, is

* The more onerous duty of properly supervising a technical bureau is noted in a recent report of a committee of the National Academy of Sciences. Irregular methods of business are encouraged by general regulations which cannot be adapted to the special requirements.

a purpose in which the engineers of our country can unite for the highest public good.

At the same time, the status of our profession may be promoted in greater degree than by the solution of any other problem of our time to which we may lend our consideration and effort.

A DESCRIPTION OF THE CHARLOTTESVILLE WATER-WORKS, ALBEMARLE CO., VA.

By Edward D. Bolton.

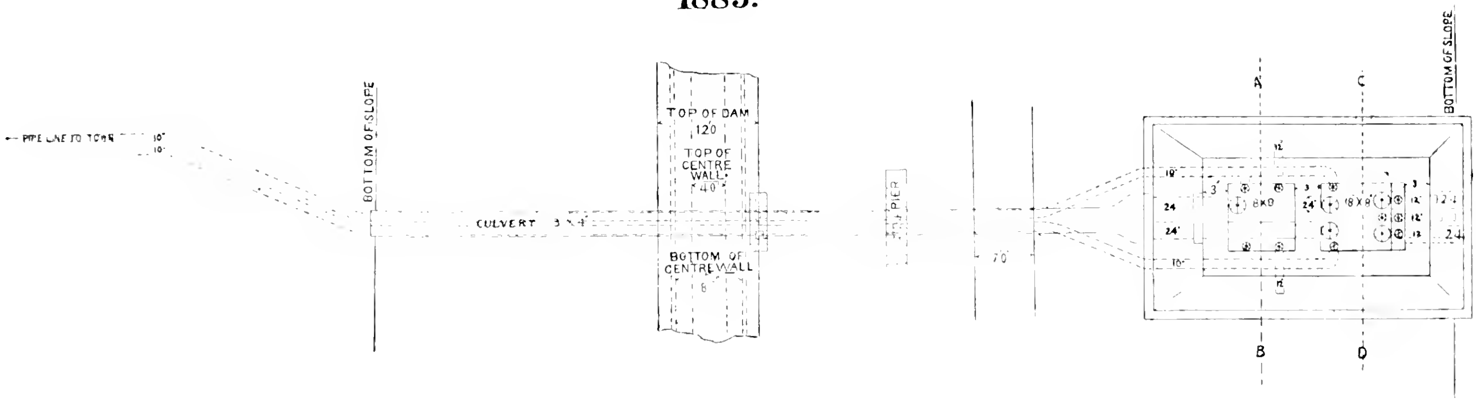
[Read before the Boston Society of Civil Engineers, November 16, 1885.]

Charlottesville is the shire town of Albemarle County, Virginia. It has within the corporation limits a population of about 3,500. The University of Virginia is located just outside the corporation, and this, with the students and persons connected therewith, together with the people living in the immediate vicinity, comprise about 2,000 more. The town and University having united in the introduction of water, provision is made for supplying a population of 5,500 and a future growth.

The plan adopted is that generally known as the "gravity system." A dam has been built across a deep and narrow valley in the Ragged Mountains, about 5½ miles beyond the town, through which a stream, fed by springs, flows, and a pipe-line has been laid, passing through University grounds, to the town. The sides of the valley are very steep and underlaid with ledges, and are covered for the most part with grass and timber, a small area of cultivated land lying farther up the valley and above high-water level. The stream flowing through the valley will furnish, in ordinary seasons, a supply far beyond the present demand, but provision has been made to store the surplus rain-fall as well, and the reservoir has such storage capacity that it will carry the town through any possible drought. The dam is 45 ft. high above the level of the meadow and 530 ft. long, and the reservoir has a water area of 32 acres at high-water level, and a capacity of 189,000,000 gallons. It is built of earth, with a core of rubble masonry through the centre, well laid in cement, and pointed on the inner or water side with Portland cement. This core is 8 ft. wide at the base at the lowest point, the width at the base varying with the height, and 4 ft. wide on top. The foundation in the centre is about 15 ft. below the general surface of the meadow and 10 ft. wide. The materials at the bottom of the foundation are solid rock, very compact rotten rock, and clayey gravel. Where the gravel and the softer portions of the rotten rock were found a bed of concrete, 30 inches deep and 12 ft. wide, was put in, and the masonry started from this. The concrete was also brought up on the inner side of the wall to the original surface of the ground in places according to the character of the soil. The stone used was a granite quarried near the site of the dam, and was very hard and compact, the finer grained stone being reserved for the gate-house. The cement used was the "James River" brand, manufactured by H. O. Locher & Co., at Balcony Falls, Va., and gave very good results. The earthwork is 12 ft. wide on top and about 190 ft. at the bottom, the

CHARLOTTESVILLE WATER WORKS.

1885.

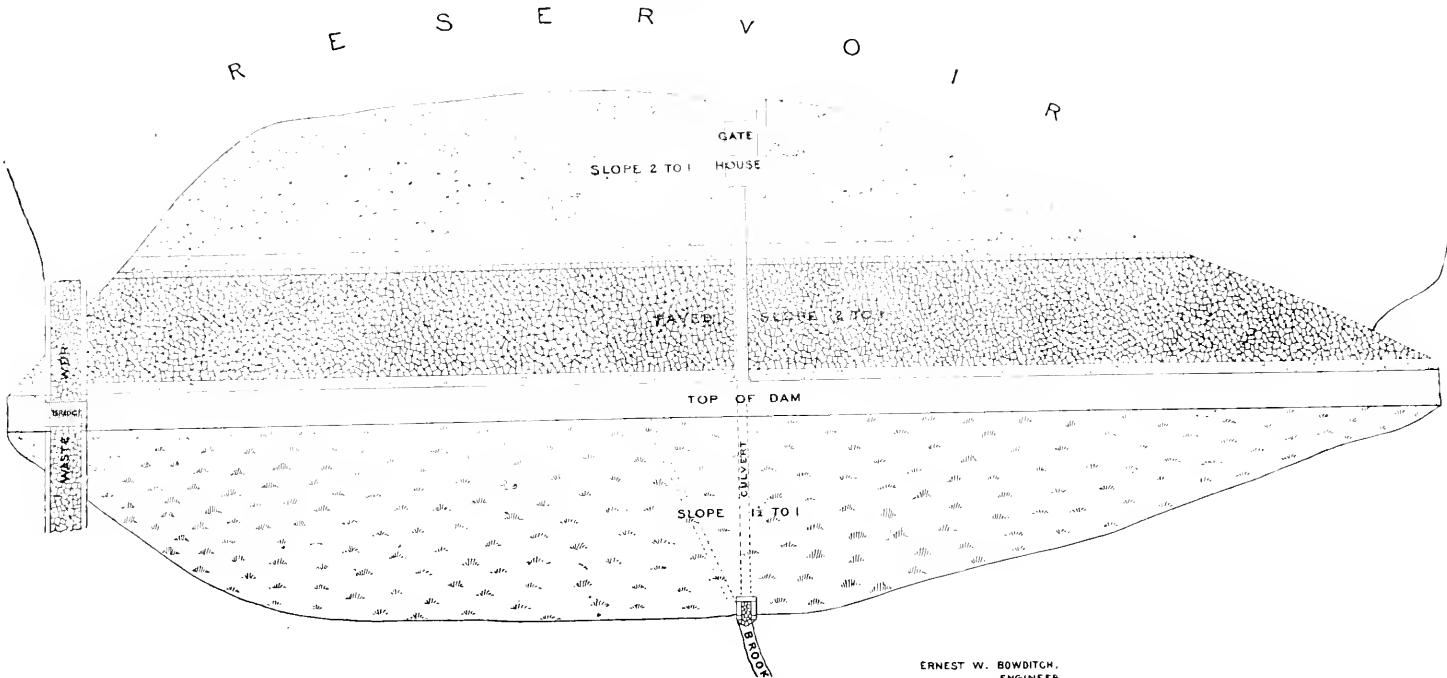


PLAN OF GATE HOUSE

ERNEST W. BOWDITCH
ENGINEER
60 DEVONSHIRE ST. BOSTON

CHARLOTTESVILLE WATER WORKS.

1885.

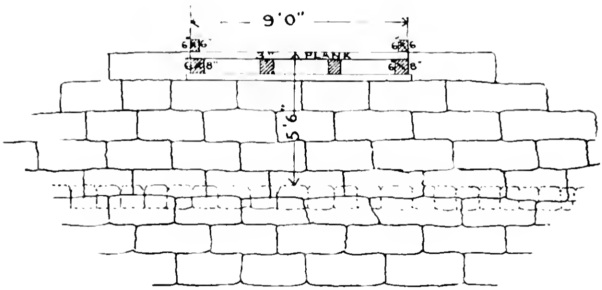


PLAN OF DAM

ERNEST W. BOWDITCH,
ENGINEER,
60 DEVONSHIRE ST., BOSTON.

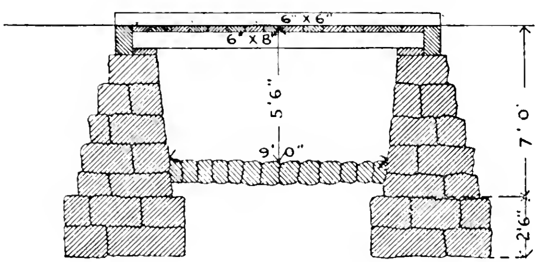
slopes being 1½ to 1 on the outside, and 2 to 1 on the inside, the inner slope being broken by a berme 7 ft. wide about midway from top to bottom, and the upper slope being paved.

As the masonry was carried up, the earth was put in place in layers and thoroughly rolled with a grooved roller, being wet when necessary,



WASTE WEIR.
LONGITUDINAL SECTION.

to make it compact. All the teaming was done over the embankment, and made to cover as much ground as possible, to avoid rutting. After the earthwork was brought up to its full height, the outer slope was



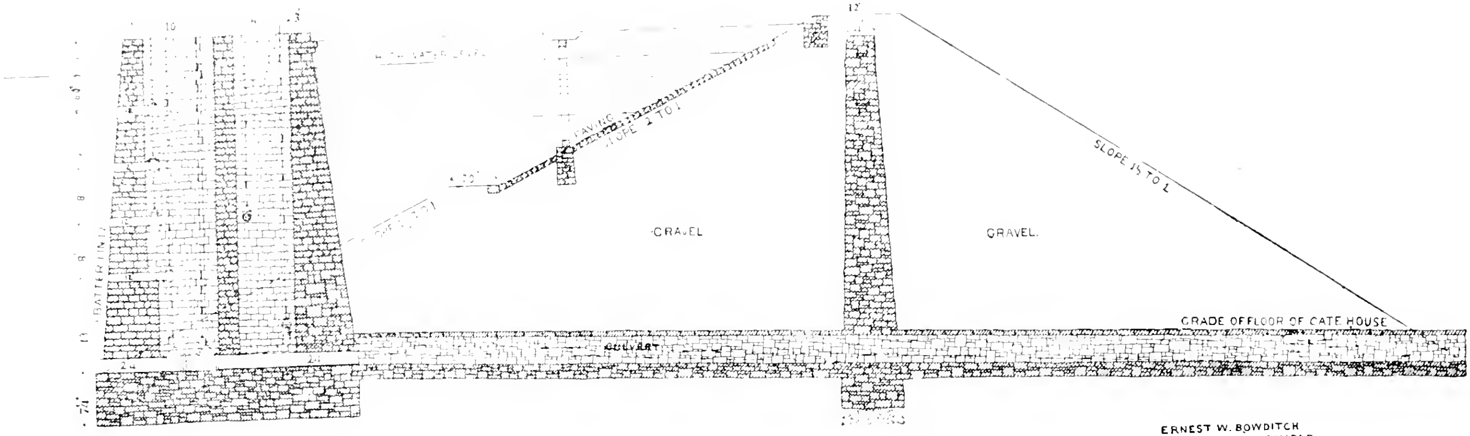
WASTE WEIR.
TRANSVERSE SECTION

dressed down, the top of the dam leveled, and top soil was put on, nine inches in depth, and the whole outer slope and top seeded.

The gate-house, which is set out into the pond, is built of the finer grained stone, with quarry faces and squared joints. It is arranged with two chambers, either of which can be used independently to supply water through the pipe line to the town. It is 14 ft. by 27 ft. on the top, the chambers being 8 ft. by 10 ft. and 8 ft. by 8 ft., divided by a partition wall 3 ft. thick, and all the walls are 3 ft. wide at the top. The dimensions at the bottom are 22 ft. by 37 ft., and the foundation, 24 ft. by 38

CHARLOTTESVILLE WATER WORKS.

1885.



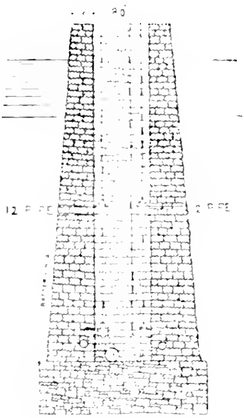
CROSS SECTION THROUGH GATE HOUSE & DAM

ERNEST W. BOWDITCH
ENGINEER.
60 DEVONSHIRE ST. BOSTON

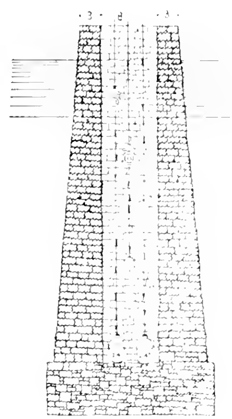
ft., rests upon a bed of very compact rotten rock, $7\frac{3}{10}$ ft. below the floor of the chambers.

To admit water to the chambers, six 12-inch cast-iron flanged pipes are built into the masonry at different heights, each provided with a gate bolted to it to control the flow of water through them, so that the water may be taken from near the surface, where the water is clearer and freer from sediment.

In this section of the country, after heavy rains, all the streams and ponds are every much discolored by the reddish clay carried along by the water, but which gradually settles out. Therefore, the best and clearest water will always be found nearest the surface, and to supply



SECTION THROUGH A B



SECTION THROUGH C-D

water to the town the inlet pipe just below the water would be opened to allow water to enter the chamber. Copper wire nettings, secured to plates so arranged that they may be dropped over the inner flange of the gates from the screens. These can be easily removed and cleaned, as they are light and convenient to handle, and as the pipe opened is always under the water, they are not liable to catch rubbish, such as leaves and sticks, or to need frequent cleaning.

The supply pipes to the town are 10-in. flanged pipe, two to each chamber, each provided with a gate. These pipes are carried through the masonry of the gate-house, under the dam through the culvert, and brought together just beyond the foot of the outer slope into one pipe leading to the town. These are so left that an additional line can be carried to the town when it becomes necessary, without disturbing the work in the gate-house or dam.

To empty either chamber, there are two lines of 24-in. flanged pipe, fitted with gates, one line running directly from the first chamber to the waste culvert, which passes through the dam to the meadow below into the bed of the brook; and the other from the first chamber to the second, and then from the second to the waste culvert, thus connecting

the two chambers, and also allowing the second chamber to be emptied independently of the first. If it is necessary to draw all the water out of the reservoir, the gates on both these lines of 24-in pipe can be opened and the water will be drawn completely down to the bed of the original brook. The gates used are the ordinary pattern of flanged water-gates, and were furnished by the Coffin Valve Company, of Boston.

At present, only a single line of 10-inch cast-iron pipe runs to the town, which is reduced after taking off a 6-inch distribution, to an 8-inch along the main street to the farther end of the town. The distribution is made with 6-inch and 4-inch pipes, which are connected together, with the exception of two lines, where it was not practicable to do so, to insure complete circulation.

There were $5\frac{6}{10}$ miles of 10-inch, $\frac{5}{10}$ of a mile of 8 inch, $1\frac{8}{10}$ miles of 6-inch, and $1\frac{3}{10}$ miles of 4-inch, a total of $9\frac{2}{10}$ miles of pipe laid. There were also 139 specials, 42 stop gates, 38 double-nozzle fire hydrants and 7 single-nozzle fire hydrants set. On the main 5 single-nozzle hydrants were used as air-cocks, and gates were put in about a mile apart, thus dividing the line into sections. The gates and hydrants were furnished by the Chapman Valve Manufacturing Company, of Boston, and the pipe and specials by the Warren Foundry and Machine Company, of New York. The work on dam and reservoir was commenced March 26th and completed October 27th. It was done under contract by McConnell & Hickler, of Buffalo, N. Y., and cost, including fittings for gate-house and incidentals, $49,293.99.

The pipe line was commenced April 6th and finished early in July. It was contracted for by Trumbull & Cheney, of Boston, and cost, including pipe, gates, hydrants, etc., $49,475.35. Land damages, right of way, and incidentals brought the grand total to $107,831.62. For house services we have used 1-inch and $\frac{3}{4}$-inch tar-coated wrought iron pipe, with lead connections where the services start from the mains.

AMOUNT OF HORSE-POWER USED IN PROPELLING STREET CARS.

By Augustine W. Wright, Member of the Western Society of Engineers.

[Read November 2, 1885.]

At the present time great interest is manifested by street railway companies regarding the question of the substitution of some motive power to propel their cars other than horse-flesh. The various systems, electrical, cable, compressed air, Honigman, steam dummies, etc., etc., are prominently before the public, and each for itself claims, if not perfection, certainly that it is better than any other system.

It appears to me that great ignorance exists upon the part of inventors and street railway companies themselves as to the amount of power required to start a street car and to maintain it in motion under average conditions. The following is an attempt toward a solution of this problem. We will begin with horse-power: Watt's experiments, made with large horses of the London brewers, gave 33,000 pounds raised one foot high in one minute as the power exerted by an average horse, and this, as you all know, is the allowance in figuring engine power. This is on

the assumption that a horse can exert a force of 150 pounds over 20 miles per diem at the rate of 220 feet per minute, or 2½ miles per hour during 8 hours. But the horse's power is very variable at different speeds. Tredgold's experiments gave 125 pounds; Smeaton, 100 pounds; Hatchette, 128 pounds; all 20 miles per diem at 2½ miles per hour. Gayffier fixed the power of a strong draught horse at 143 pounds, 22 miles per diem at 2¾ miles per hour, and an ordinary horse, 121 pounds for 25 miles per diem at 2½ miles per hour.

As the speed of a horse increases his power of draught diminishes very rapidly, until at last he can only move his own weight.

The following table shows the results obtained by different authors; those of Tredgold being for six hours' daily labor, and those of Wood for ten hours:

Velocity. Miles per hour.	—Tests of draught according to— Leslie.	Tredgold.	Wood.
2	100	166	125
3	81	125	83
4	64	83	62
5	49	42	50
6	36	..	42
7	25	..	36
8	16	..	31
9	9	..	28
10	4	..	25

From the above table, it appears that, according to Wood, at 4 miles per hour a horse can draw only half his load at 2 miles; at 8 miles, only a quarter, etc.

Sir John Macniel estimates his power at 60 lbs., moved 8 miles per diem at same velocity (Gillespie). Wood's Practical Treatise on Railroads contains an interesting chapter on horse-power. He made many experiments. He quotes an interesting memorial to the House of Commons, May 3, 1836, from the proprietors of various (33) stage coaches running out of Liverpool, employing 709 horses. These horses traveled an average distance of 13 miles daily, at a speed not exceeding 10 miles per hour, and the stock had to be renewed every *three years*.

Tredgold assigned 37 pounds as the power that a horse should exert over a distance of 10 miles in a day at a velocity of 10 miles per hour, or one hour's work. This was founded upon his experiments on stage coach horses. They endured this service only three years.

The speed of North Chicago City railway cars is 6 miles per hour, including stoppages, and the average time of service is reckoned at five years for each horse, traveling upon selected cobble stone pavement. Before the cobble stone was adopted the average railway service was four years per horse. The chief street railways of the United States estimate the railroad life of their horses at from three to five years.

May 17th, 1881, I had the honor of addressing you on "The Best Pavement for Horse Railroad Tracks." Permit me to quote from that paper. "I recently made the following tests of the force required to start car 110 of the North Chicago City Railway Co. and to keep it in motion after it was under way, using a Fairbanks dynamometer. The track has a

grade of two-tenths of a foot per hundred. (This grade is up and down, changing, say, each 250 lineal feet, and is compensated, as the observations were taken upon up and down grades.) The track was not free from sand. Between Chicago avenue and North avenue, on Clark, Division and Clybourn avenues, 88 tests with an average of 14.8 passengers, weighing (estimated at 140 lbs.), with car, 6772 lbs. The force required to keep the car in motion at an average speed of five miles per hour, including stops, averaged 109.5 lbs., or per ton 32.3 lbs. This is on an old, worn-out iron rail. Between Chicago avenue and Madison street, on Clark, on new steel rail, 53 tests, with an average of 20.9 passengers, gave 59.8 lbs. as the force required to keep the car in motion. This is an average of 15.6 lbs. per ton. The car made 17 starts on this track with an average of 18.7 passengers. Average force exerted to start, 426.5 lbs. Average per ton, 116.5 lbs. On the first mentioned track, 30 tests, with an average of 18.1 passengers, gave an average force of 487 lbs.; average per ton, 134.6 lbs.

Recapitulated, the force exerted per ton was, in pounds:

On good track, to start, 116.5 : to keep in motion, 15.6.
On bad track " " 134.6 : " " " 32.3.

These tests indicate the great loss of power entailed by bad track, and also the great loss in starting; and the better the track, the greater the relative loss in starting. On the poor track, 134.6 lbs. per ton was exerted to start, and this is 4.1 times the force required to keep the car in motion. On good track, 116.5 pounds was the force required to start, but this is 7.1 times the force required to keep the car in motion.

Upon the North Chicago City Railway, the average weight of car and its load is 7,740 pounds, or in short tons, 3.87. Passengers averaged at 140 pounds. Our track is now all good. The average force, therefore, exerted in propelling one car is $3.87 \times 15.6 = 60.372$ pounds when the car is in motion, and $3.87 \times 116.5 = 450.855$ pounds force to start. The horses average 137.97 minutes, service per diem. One hundred and three tests upon 17 different cars, open and close, on various lines with different drivers, made by me on different days and hours, give the following average for the horses: Time consumed in stopping, during which no power is exerted by the horse, 13.22 minutes. Time from starting until average speed is reached, 7.88 minutes.

Now the horses average as per above 137.97 minutes daily service.

Deducting time they are not exerting force, 13.22 minutes daily service.

Leaves actual work, 124.75 minutes daily service.

Of this power is exerted to maintain motion, 116.87 minutes daily service.

And extra power is exerted during 7.88 minutes daily service.

The horse power, therefore, exerted in propelling a North Chicago railroad car with its average load by a team in its average day's work is:

$$\frac{450.855 \times 311.5 \times 7.88}{33000} = 33.53 \text{ H. P. starting.}$$

$$\frac{60.372 \times 623 \times 116.87}{33000} = 133.22 \text{ H. P. maintaining motion.}$$

Total .... 166.75 H. P.

This is used during 137.97 minutes, average per minute, 1.208 H. P. per team; or for each horse, 604 H. P.

Upon a poor track, my previously quoted experiments show that this power would be about doubled, or 2.4 H. P. would be used per average car. About $\frac{1}{5}$ of the horse power is used in starting the car (20.1 per cent.). Mr. Angus Sinclair experimented upon the Third Avenue Elevated Railroad, New York, and estimated that the average pull on the draw-bar was five times greater than it would have been if the motion of the train could have been continuous. See *National Car-Builder.*

A. M. Wellington found by his experiments that the initial friction in starting trains of loaded cars was 5.47 times that required to keep them in motion at a speed of 10 to 15 miles per hour. See Trans. A. S. C. E., December, 1884. Charles E. Emory, Ph. D., found 11.8 pounds per ton of 2,000 pounds to be the resistance on straight and level track in New York. This is less than my average, but his tests were probably made on a centre-bearing rail, the usual rail in New York, and this we know offers less resistance to progress, as the head is comparatively clean, while the step-rail head upon which I experimented was *level with the adjoining outside pavement*, and consequently covered more or less with sand and dirt.

D. K. Clarke, in his work on tramways, states that H. P. Holt found the resistance per gross ton on straight, level track varied from 15 to 40 lbs.: Henry Hughes, 26 lbs.—often much more, occasionally less; M. Tresca, 22.4 lbs. per ton. Subsequently M. Tresca removed two flanged wheels on one side of the car, and then found the resistance 15.25 lbs. Mr. Clark assumes 20 lbs. per ton, and says at times it is 40 lbs. per ton. "An average of 30 lbs. per ton may be taken for the calculation of the ordinary tractive force." In his second volume he states: "The average resistance (30 lbs. per ton), already in the first volume adopted for calculation, may be re-adopted, although an occasional maximum of 60 lbs. per ton may be reached, and, on the contrary, a minimum of 15 lbs. per ton when the rails are wet and clean, straight and new.

Mr. Clarke's remarks refer to grooved rails, which offer greater resistance than the step rail. General Gilmore estimates this resistance at $16\frac{2}{3}$ lbs. per short ton with track in average condition for United States. Mr. C. B. Holmes, President and Superintendent Chicago City Railway, stated that his cable railway required for ordinary operations engines of 477 horse-power; of that it took 389 horse-power to move the cable and machinery. Eighty-eight horse-power ($18\frac{1}{2}$ per cent.) was used for the propulsion of 240 cars, weighing 6,000 lbs. each, and carrying each 5,000 lbs. of passengers. The average speed was 9 miles per hour, or 792 feet per minute. This statement would indicate that only $\frac{88}{240} = .367$ horse-power per car was required, while my experiments would give: as 3.87 (my average load) is to 5.5 (his average load), so is 1.208 horse-power (used by me) to 1.71 horse-power required.

There must have been some mistake in his test, for .367 horse-power = 12,111 foot-pounds. As his speed is 792 feet per minute, the tractive force exerted would be only 15.29 pounds for 5.5 tons, a resistance of less than 3 pounds per ton (2.78 pounds), which is impossible upon a step rail.

Our fellow-member, D. J. Miller, M. E., while employed upon the above-mentioned cable railway, made experiments upon the horse-power used. He found that at an average speed of 6.85 miles per hour or 602.8

feet per minute. 1 horse-power was required for each ton of cable and machinery and .2 of a horse-power for each ton of car and its passengers. For my average load of 3.87 tons, this would equal .774 horse-power, instead of 1.2 horse power as estimated by me. Mr. Miller's .2 horse-power = 6,600-foot pounds. His average speed being 602.8 feet per minute, his resistance to traction could have been only 10.95 pounds, including starting the cars. This is 3.94 times the resistance found by Mr. Holmes, but nearly 30 per cent. less than my experiments would indicate. Mr. Miller, however, *assumed* the weight of passengers, having no count of their number, and must have overestimated the load and experimented with the track unusually clean. My average of 15.6 pounds per ton, agreeing so nearly with that of M. Tresca, 15.25, as above quoted, confirms my opinion that it cannot be far wrong. While it is true that M. Tresca's experiment quoted was with only one flanged wheel upon each axle, yet that wheel traveled in a grove, and the resistance could not vary much from my two flanged wheels not in a groove. The car wheels in Chicago are 30 inches in diameter. The horses of the North Chicago Railway weigh about 1,100 lbs. each. The speed at which they travel upon the road averages 623 feet per minute or 7.08 miles per hour. Their average horse-power developed being each .604 horse-power, equals 19,932 foot-pounds. Divided by 623, the distance per minute, gives 31.99 lbs. tractive force. Leslie's estimate at 7 miles per hour was 25 lbs. Wood's estimate was 36 lbs., at the same speed.

Our horses work daily 2 hours 17.97 minutes, but *seven* days in the week, unless prevented by some unforeseen cause.

I have neglected extra resistance caused by curves, because our lines are chiefly tangents, and it is very difficult to measure the force exerted upon curves, for it varies greatly between 400 and 1,000 lbs., upon the dynamometer with the same car and load. My tests were so unsatisfactory upon curves that I have thought it best to omit them entirely. Then, too, the horse walks around the curve, and the lessened speed in a measure offsets the increased resistance.

The greatest exertion of force upon a tangent during my dynamometer experiments occurred in starting a loaded car. It was 1,500 lbs. average per ton 283.5 lbs. Passing through some slush, caused by snow thrown upon the track, it equaled 75.6 lbs. per ton.

In estimating for any independent motor to propel a street car upon the North Chicago Railway, I would take the maximum load and resistance. I have known of 120 passengers upon an open car. Averaging them at 140 lbs. each, equals 16,800 lbs.; car, 4,800 lbs.; total, 21,600 lbs., or 10.8 short tons. Speed in starting, 0 to 623 feet per minute; average, 311.5. $\frac{10.8 \text{ tons} \times 311.5 \text{ feet} \times 283.5 \text{ lbs.}}{33,000} = 28.9$ horse-power required; a small portion of this power would be constantly employed, but it must be in reserve. With the electric or cable system no such allowance would be required, for the reason that this excess of power is only needed to *start* the car, and my experiments indicate that the car is starting only one-seventeenth of the time, while it requires no power one-tenth of the time. For each 17 cars upon a line, therefore, it would be necessary to furnish power to *start one* car and to maintain sixteen cars

in motion, less the power when stationary, as it is not probable, nor is it necessary, that all should start at the same instant.

During my experiments the cars stopped upon an average each 1,478 lineal feet. We stop only at street intersections, or at the centre of blocks more than 500 feet long.

The following returns are taken from the sixteenth annual report of the Massachusetts Board of Railroad Commissioners :

Name of Railroad.	Number of horses owned.	Number of miles run.	Number of passengers carried.	Average no. passengers per round trip.
Highland...........	909	1,670,347	10,452,441	43
Lynn & Boston.....	608	1,052,296	6,361,009	50
Metropolitan.......	3183	6,046,879	34,574,135	38
Middlesex..........	601	1,047,411	7,099,892	45
South Boston.......	857	1,470,261	9,706,299	41
Total........	6158	11,287,196	68,196,776	Average, 43.4

From the above it appears that the stable average daily distance traveled by the above horses equals 10.04 miles, found by dividing total number of miles run by total number of horses, and this by 365 and multiplying by 2

$$\frac{11,287,196 \times 2}{6158 \times 365} = 10.04.$$

The average number of passengers for these five railroads per round trip being 43.4 per single trip, equals 21.7. Averaging them at 140 pounds, equals 3,038 pounds. Add weight of car, 4,800 pounds, equals 7,838 pounds, or 3.919 short tons, which is in excess of my average load of 3.87 tons.

It is fair to assume that these horses are worked to the best advantage and that this is all that can be expected of a horse upon a tramway.

The stables of the North Chicago Railway are located at or near one end of each line. The horses are in exellent condition. Their mileage could not be increased, even if it was thought desirable, unless they were changed from car to car upon the road, and this would cause delay and inconvenience. They now make two round trips and could not make more without adding 50 per cent. to the distance they now travel or changing upon the road.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 18, 1885:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M., Vice-President L. Frederick Rice in the chair, thirty-nine members and three visitors being present.

The record of the last meeting was read and approved.

The Secretary reported that the Committee on the Convention of the American Society of Mechanical Engineers had attended to its duty as directed, and that about eighty copies of the pamphlet on the Boston Main Drainage Works had not been distributed. The report of the Committee was accepted and the Committee discharged.

On motion, it was voted: That the Secretary be instructed to send a copy of this pamphlet to the members of the Society present.

The Committee on the Relation of Army and Civil Engineers in the Government Service presented a report giving all attainable information. On motion, the report of the Committee was accepted.

On motion of Mr. Fred. Brooks it was voted: That the committee be authorized to send a delegate to the Convention at Cleveland, and that the delegate be instructed to collect information and report to the Society.

The report of the Committee on furnishing room was presented verbally, and further time granted.

On motion of Mr. Henry Manley, it was voted: That the Boston Society of Civil Engineers tenders its thanks to the American Society of Mechanical Engineers for its kindness and courtesies extended this society during the sixth annual meeting of the American Society of Mechanical Engineers, held in Boston, Nov. 10 to 14, 1885.

On motion, it was voted: That regular business be postponed until after the reading of papers.

Mr. E. D. Bolton read a paper on "The Charlottesville Water-Works."

On motion, it was voted: That the thanks of the Society be tendered to Mr. E. D. Bolton for his paper.

Mr. William Whittaker read a paper on "The Worcester Sewerage Tunnel."

Messrs. Edward H. Brooks, Winfield S. Chaplin, Sophus Haagensen, Hersey G. Palfrey and Charles H. Parker were proposed for membership, recommended respectively by T. W. Davis, C. W. Folsom; S. E. Tinkham, C. W. Raymond; C. W. Raymond, F. P. Stearns; E. C. Clarke, C. W. Folsom; H. Manley, S. E. Tinkham.

Messrs. F. L. Libbey, D. Porter, W. T. Pierce and U. S. G. White were elected members of this Society.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

ANNUAL MEETING.

DECEMBER 2, 1885:—Club met at 8 P. M., at Mercantile Library. Vice-President McMath in the chair and 37 members present.

Minutes of last meeting were read and approved.

The Executive Committee reported that the letter ballot should be carried out

on the plan adopted by the American Society of Civil Engineers, requiring every member to indorse his name on the envelope inclosing his ballot ; that President Moore had been authorized to subscribe for a share of the membership stock of Mercantile Library.

Mr. Jno. H. Kinealy was proposed for membership by Messrs. J. B. Johnson and W. H. Allderdice.

The Secretary read his report of the work of the Club for the past year.

St. Louis, Dec. 2, 1885.

Mr. President and Gentlemen : Your Secretary respectfully submits the following report of the proceedings of the Club for past year :

Sixteen meetings have been held, with an average attendance of 25 members and 2 vi itors. President Moore has occupied the chair at all but two meetings, when Vice-President McMath presided.

Regularly announced papers have been read at every meeting. Twenty-six papers have been presented, fourteen of which have been published.

The following members have contributed papers : Mr. Robert Moore, Mr. S. B. Russel, Mr. Oekerson, Mr. J. B. Johnson (3 papers), Mr. Sobolewski, Mr. Aubin, Mr. Bouton, Mr. Constable (2 papers), Mr. Wise, Mr. Macklind, Mr. Taussig, Messrs. Caldwell & Miller, Mr. Nipher, Mr. Tully, Mr. Baker, Mr. Holman, Mr. White, Mr. Pond, Mr. Bryan, Mr. W. H. Allderdice, Prof. Potter, Chairman of the Committee on Smoke Prevention, and Mr. Clark.

There are now 120 qualified members. Meetings have been held at three different places during the year ; nine of them at the Mercantile Club rooms, three at Mercantile Library, and four at Washington University.

An amendment to Sec. 7 of the By-Laws was adopted, requiring applicants for membership to give their qualifications, and pledge themseves to conform to the requirements of the Constitution and By-Laws.

Thos. D. Miller, Secretary.

The Librarian and Manager of the Journal then read his report :

St. Louis, Mo., Dec. 2, 1885.

To the President and Members of the Engineers' Club of St. Louis : Your Librarian and member of the Board of Managers of the Associated Journal would respectfully beg to submit the following as the first annual report of this officer under the new constitution :

The additions to the Club library during the year consist mostly of the publications of other societies, among which the following are the most important : Transactions of the American Society of Civil Engineers : Transactions of the Liverpool Engineering Society (5 vols.): Proceedings of the Philadelphia Engineers' Club : Proceedings of the Fifth Annual Meeting of the American Water-Works Association : the Proceedings of the State Associations of Engineers and Surveyors of Connecticut and of Indiana, and Abstracts of Papers read before the Society of Arts of the Massachusetts Institute of Technology ; also, Main Drainage Works of the City of Boston, and System of Railroad Bridges for Japan (2 vols).

This Club does not subscribe for any periodicals or purchase any books, its facilities in connection with the Mercantile Library making it unwise that it should undertake the task of collecting a library of its own. The duties of Librarian, as such, are therefore very light. By our new constitution, however, the Librarian represents the Club on the Associated Journal, and it is this fact gives to the position of Librarian its principal significance.

As a member of the Board of Managers of the Journal your representative has the pleasure of reporting its affairs in a very prosperous condition. Only one new society has joined the Association during the year, but the joint organization is fulfilling its mission, and the Journal has come to be recognized as the largest source of valuable engineering information of an original and varied character in America. Its influence in unifying the sympathies and interests of the profession

in this country will never be accurately known, but that it is having a very wholesome influence in this direction is evident on all sides.

It is thought that the value of the JOURNAL to studious engineers has been greatly increased during the year by means of the Index Department. Inasmuch as this enterprise originated with your representative, he was charged with inaugurating it, and he volunteered to superintend the work for the first year. At first it was hoped that considerable assistance could be obtained from other sources, and it was even proposed to divide the work among the various clubs. Both of these possibilities have proved impracticable. It is evident the supervision must be by a single individual, so that all matter must be sent to him for coördination, and to prevent duplicating on the one hand and omissions on the other. After a large amount of correspondence, in his efforts to get efficient assistance, none of which has proved either very great or long-lived, the manager concluded it was cheaper to do the work himself, especially in those avenues which were open to him. His original purpose, however, was not simply to divide the labor, but to put the several special departments of the work under leading engineers in the several fields, since these would be the best judges of the merits of an article in any of their departments. He soon found that these leading engineers were the very men who had no time to devote to such matters, and rather than trust it to novices he preferred to do it himself. The amount of correspondence demanded in future will, therefore, be much less than it has been in the initial year; but it will always be large. It is impracticable to obtain municipal and State reports regularly on a single application. It seems there is no regular list of beneficiaries in such cases, and a single solicitation brings but a single document, even if it does that. This department of the Index has not been nearly as complete as it should be.

The work of preparing the index notes will therefore always be very onerous when it falls almost wholly on a single individual, as it seems it must, it requiring at least three full days' work to prepare the index notes for one issue. The past year, which was recognized as being experimental, has demonstrated this fact. With this acknowledged, it would seem too much to ask of one man that he do this work gratuitously. It has been proposed by some (not members of the Board of Management) that a central headquarters be established where all this work, together with that of the Secretary of the Board, should devolve on one man, and he paid a liberal salary. This is the ideal arrangement, and is a good ultimate result to look forward to, but the Association cannot afford to undertake such responsibilities at present. If this department is to be sustained, therefore, it would seem that for a few years, at least, it must devolve on some member of the Association, not necessarily a member of the Board of Managers, who can be found willing to undertake it.

It has been shown, too, during the year, that this work cannot be done by one of our regular engineering periodicals. Since "imitation is the highest praise," the Association should feel highly flattered at the starting of an "Index Department," modeled directly after ours, some months since in one of our engineering journals. The editor evidently found himself greatly handicapped, however, since a *complete* index would give his rivals too much free advertising and an index made up from his own columns and such foreign periodicals (mostly French and German) as could not be considered rivals, was of little value. He therefore wisely discontinued it after a weakly existence of some six months.

The disposition of such matter as comes to the Index Department of the JOURNAL is also an unsettled question. It evidently does not belong to the local club, for they have no more claim upon it than any other society of the Association. If this matter was all valuable to one man the problem of remuneration would be partially solved, for the selling price of such matter as has come to this department of the JOURNAL during the past year is upward of fifty dollars, aside from

the municipal, State and Government reports, which are distributed gratuitously; and aside too from the publications of the State Geological Survey of Pennsylvania which are now distributed to certain public institutions, but which are sold to private individuals, over one hundred dollars worth of which have been sent to this department; and aside too from the Proceedings of the Institution of Civil Engineers, London, of the American Society of Mechanical Engineers, and of the American Institute of Mining Engineers, the cash value of which is unknown.

If all such matter had their list-price value to the index manager they would go far toward recompensing him for his labor, but it is evident that only a small part of such matter is of real cash value to any one man. It would be valuable, however, to the local club, and if such club would agree to take it off his hands at a reduced price, the Association could, perhaps, afford to assist to the extent of the value of the index to the average member, and so a proper disposition of the matter be made, and a fair remuneration guaranteed for the labor necessarily involved.

Your representative in the Board of Management has been induced to outline what appears to him a fair and practicable solution of the problem in justice to his successor, and in view of promised relief from the several trusts that have been committed to his care.

J. B. JOHNSON, Librarian.

President Moore entered and took the chair.

The Treasurer then read his report.

ST. LOUIS, Dec. 2, 1885.

President and Members of Engineers' Club of St. Louis:

I have the honor to submit the following report:

Balance received from E. D. Meier, Treasurer, Dec. 31, 1884		$ 58 79
COLLECTIONS TO DATE.		
Initiation fees		115 00
Dues for the year 1883		4 00
" " " " 1884		28 00
" " " " 1885		333 91
Total collections to date		$569 70
DISBURSEMENTS TO DATE.		
To H. G. Prout for Journal	$362 75	
Exchange on drafts to Prout	75	
Printing, stationery and postage	110 20	
To janitor of Washington University	3 00	
Total disbursements		476 70
Balance cash on hand		$ 93 00

M. L. HOLMAN, Treasurer.

The President read the following report of the Executive Committee.

The doings of the Executive Committee having been reported to the Club from time to time during the year, as provided in the constitution, it only remains for the annual report to sum up the years' work in the briefest possible terms.

During the past year the Committee have held 15 meetings. They have recommended for ballot by the club the names of 25 applicants for membership, all of whom were duly elected. They have received four resignations and have declared three forfeitures for non-payment of dues.

They have audited and approved bills against the Club amounting to $482.45, of which $362.75 were on account of the JOURNAL, and $116.20 were for other dues, mainly printing and postage.

They have carried out so far as was practicable the very admirable programme

of papers prepared by their predecessors, and have outlined a similar programme for the ensuing year.

On the whole, the last year has been for the Club a year of prosperity. The membership has been largely increased, the interest of the meetings has been well sustained, and a number of papers of marked and permanent value have been brought out — papers which have well rewarded those who have heard them read, and in their printed form fully demonstrated the value of the Club to the profession at large.

Looking to the future, the matter of greatest immediate importance to the welfare of the Club is the provision at an early day of a permanent home—a place not only for the holding of meetings, but also one which shall be open at all times as a reading room and study for the use of members. This much-desired object can best be accomplished in connection with some other organization with like aims; and for us the best ally is unquestionably the Library Association, in whose building our meetings are now held. If the plans of the Association are carried out in accordance with the now confident expectations, a new building will shortly be begun in which, if we do our part, quarters suitable for our wants will be provided. And the successors of the present committee should be charged with the duty of co-operating with the Library Association in the accomplishment of this end.

Another matter worthy of the attention of the Club is that of making oral discussion of professional questions more of a feature of our meetings. Nothing adds more to the interest of meetings than such discussion, and, if the members make it a point to refresh themselves a little on the points to be brought up, nothing is more profitable.

For the preservation of the more important features of such discussion the propriety of employing a stenographer to report them, after the manner of many similar bodies, is at least worthy of consideration.

All of which is respectfully submitted. ROBT. MOORE, President.

Mr. Robert E. McMath, chairman, then read the report of the Committee on the Status of Civil Engineers in the service of the General Government.

To the Engineers' Club of St. Louis:

Your Committee, appointed March 18, 1885, "to consider and report on the best means of improving the status of civil engineers in the service of the general government," and which was on May 13 empowered to correspond and confer with similar committees of other societies, respectfully reports:

That to pursue successfully the subject committed to our consideration will require the coöperation of all to whom it may have interest, whether that interest arise from general and wholly disinterested consideration of the welfare and progress of the country in the line of public works, from apprehension lest the present official position of individuals, or of a class, may be unfavorably affected by any action that may be proposed, or from hope that such action would advance individuals, or a class in position, or give them an opportunity to win reputation and the substantial rewards of professional success. In the way of securing such coöperation, your committee has made overtures and suggestions in several quarters, and, from the responses received, is satisfied that no practical result is immediately attainable. We have informally submitted a rough outline of what might be done, in several alternate forms. Our suggestions for discussion, and they were no more, have not been received with favor, nor has an acceptable substitute been suggested to us. We, therefore, conclude that at present the subject lacks the definiteness in respect to need and remedy which would exist if the matter was fully understood; and, therefore, that it is not advisable to bring the subject forward to the public until development of a real want brings harmony in thought and action.

It is known to some of the Club that a committee, similar to ours, was appointed by the Cleveland Club at our suggestion, which committee proposed to us that we should undertake the accumulation of facts and arguments and to prepare a plan of action, while they would attend to organization and correspondence details. To this proposition we raised no objection. Later the Cleveland committee broached the subject of a meeting, at Cleveland, of representatives from clubs and others. To this proposition we at no time have given assent, but on the contrary discouraged it, giving as reason, that, until some ground of common action was arrived at by correspondence, a meeting must be unprofitable.

By a circular dated Oct. 27 a formal call for a meeting was sent out by the Cleveland committee to the several clubs and societies. The annexed copy of this circular reads:

THE CIVIL ENGINEERS' CLUB OF CLEVELAND,
CLEVELAND, Ohio, Oct. 27, 1885.

To Thomas D. Miller, Sec'y Engrs.' Club, St. Louis:

No objection having been raised to Cleveland as a place of meeting, the proposals as to date having varied from November 1 to November 30, and several societies having not yet appointed delegates, we deem it advisable to name Thursday, Friday and Saturday, December 3d, 4th and 5th, as the time of meeting of representatives for discussion of the status of Civil Engineers in Government service.

Meanwhile it is urged that each committee carefully consider the matter, and collect all information possible, so that the convention may use its time in considering the future and not the past.

We desire, and are advised by other committees to urge, the attendance at the meeting of any and all engineers interested in the subject, and you are requested to notify your Club to that effect.

Please advise us at once of the name and address of the delegate from your society, positively whether he will be present, and also of any others of your Club who propose to attend, so that delegates may be accorded special arrangements for hotel rates, etc. Of this and other details your delegate will be informed.

By Order of the Committee,
WM. T. BLUNT, Secretary,
44 Euclid avenue.

Of the same date, October 27, another circular was sent out addressed to selected individuals. This circular reads:

THE CIVIL ENGINEERS' CLUB OF CLEVELAND,
CLEVELAND, Ohio, Oct. 27, 1885.

Robert E. McMath, C. E., St. Louis, Mo.:

DEAR SIR: The undersigned Committee, by authority of our Club, on August 7th issued a circular to the Engineering Societies throughout the country, proposing a meeting of representatives to discuss the subject of the Relation of Army and Civil Engineers on Government work, and the propriety and method of obtaining laws which shall place Civilian Engineers on an equal footing with Army Engineers on purely *Civil* Engineering work of the Government.

Our proposition in brief was:

Each Society to appoint a Committee. Each Committee to appoint a delegate as member of a Central Committee, which shall meet to discuss the question in all its bearings, and, if possible, formulate some action which all Societies may support without offence to individuals or to the spirit of their union.

Each local Committee to report the action of the meeting back to its Society, with such recommendation as it sees fit. Each Society to decide thereupon whether it will adopt the action of the Central Committee, and such as do so to combine in action according to details to be arranged hereafter.

We also suggested Cleveland as a place of meeting.

This circular, with those of minor importance since, has elicited answers from all but three of the Societies addressed, and we are led to expect a large representation.

We desire, and are advised by other Societies to request, the presence also of some prominent engineers other than the delegates, and you have been named as one particularly interested in the subject, and whose advice will be valuable. You are therefore especially requested to attend the meeting in this city on Thursday, Friday and Saturday, December 3d, 4th and 5th.

Please notify us as soon as possible whether you will be present, so that those

attending may be accorded special arrangements for hotel rates, etc. Of this and other details you will be further advised.

If you are not able to attend, a concise statement of your views on the subject is respectfully requested. By Order of the Committee,

WM. T. BLUNT, Secretary,
44 Euclid avenue.

JOHN EISENMANN,
WALTER P. RICE,
J. J. LAMAN,
WM. T. BLUNT,
JAMES RITCHIE,
} Committee.

Please advise us of others.

Your Committee had contemplated sending a delegate to the Cleveland convention, and Mr. Ockerson had been informally selected for that purpose; but at a meeting, November 19, after the last Cleveland call, dated October 27, it was decided that such a course would not be in the interest of the ultimate good of the cause, since the conditions under which any action could be taken at Cleveland were so very unfavorable.

Since the statement had been widely published that St. Louis would be represented, it was proper that notice should also be given that St. Louis would not. We therefore sent out the following:

ST. LOUIS, MO., NOV. 19, 1885.

The undersigned Committee of the Engineers' Club of St. Louis would respectfully call your attention to the following action:

Whereas, The Engineers' Club of St. Louis did on March 18, 1885, appoint a committee to "consider and report on the best means of improving the status of civil engineers in the service of the general government," and

Whereas, Said Committee after due deliberation decided that this subject was not of sufficient general interest or importance to justify the Club in initiating or supporting a movement tending to simply legislate in the interest of a certain class, and

Whereas, The Committee in accordance with these views reported to the Club on May 13, 1885, that it "regrets to see the discussion of the subject turning aside from the broad question of creating an organization for the conduct of public works." And furthermore that "to this question personal matters, past, present or future, the value of the different schools and modes of training, or the honesty and truthfulness inculcated through certain associations, are alike foreign. There seems, therefore, to be need for conservative influence lest the utterances of individuals be taken as expressing the views and wishes of the engineering profession, and lest a discussion of a pure question of public policy degenerate into a controversy about matters of no consequence;" and

Whereas, The Committee was continued to consider this broader question and make an effort, through "correspondence and conference" with other societies, to reach some common ground of action ultimately terminating in a convention to formulate a plan for creating an organization to conduct our public works and all questions relating thereto being still under consideration,

Therefore be it *Resolved*, That this Committee does not deem it expedient to send a representative to the convention called to meet at Cleveland for the purpose of promoting class legislation, a matter foreign to the declared purposes for which this Committee was continued.

Resolved, That copies of these resolutions be furnished the several engineering societies of the country.

ROBERT E. MCMATH,
J. A. OCKERSON,
J. B. JOHNSON,
H. S. PRITCHETT,
} Committee.

To this notification the Cleveland Committee has responded by the following:

CLEVELAND, O., NOV. 23, 1885.

DEAR SIR: We are just in receipt of a circular from the Committee of the Engineers' Club of St. Louis, also addressed to other clubs, giving notice that the said Committee, for reasons given, deems it inexpedient to send a delegate to Cleveland "for the purpose of promoting class legislation."

As this is manifestly unjust to all who have interested themselves in the subject, whether in Cleveland or in other cities, and as it comes to us after they have notified us under date of November 6 of the appointment of a delegate who would attend if the character of other delegates were satisfactory to them, we deem it advisable

to send this additional circular to correct the list of delegates by omitting that of St. Louis.

The communications from this Committee, as well as all those received by it, with the single exception of the earlier ones from St. Louis, have invariably outlined *not* a class legislation, but a conservative, professional and not-political course for the welfare of the country as well as that of civilian engineers.

This much we consider necessary for the protection of all who have interested themselves in the meeting.

By order of the Committee, WM. T. BLUNT, Secretary.

The Cleveland Committee disavows any intention to have the narrow class question of Civil and Army engineers considered at the meeting, and we by no means question their entire sincerity, but we consider that they have been very unfortunate in the matter of calling the meeting, especially in the issuance of two circulars, of the same date, in which the purpose of the meeting is diversely stated, and in the one addressed to individual engineers, "As one particularly interested in the subject, and whose advice will be valuable"; the class question, "Relation of Army and Civil engineers on government work," is particularly conspicuous.

Whatever might be the action of a meeting called in such terms, and in this twofold way, no disclaimer would free it from the charge of being intended to benefit a class only.

We therefore report our action in the matter to the Club, and submit for your consideration the following recommendations:

1. That your present Committee be discharged.
2. That you appoint a new Committee to consider by correspondence and conference with similar Committees and representative men the question of a suitable organization for the conduct of public works under the general government.

Your Committee deems it proper to say that the original resolution, of March 18, 1885, under which the Committee was appointed is, in a measure, open to the same objection we made to the calls of the Cleveland Committee, of appearing to contemplate action in the interest of a class rather than in the interest of a public service.

ROBERT E. MCMATH,
J. A. OCKERSON,
J. B. JOHNSON,
H. S. PRITCHETT, } Committee.

Moved and seconded: That the report be received and Committee discharged. Carried.

Moved and seconded: That the action of the Committee be indorsed by the Club.

After a long discussion, the motion was laid on the table.

Moved and seconded: That this Club elect a delegate to attend the Cleveland Convention. Lost.

The Committee on nominations of officers for the ensuing year reported for President, Robert E. McMath; for Vice-President, William B. Potter; for Secretary, William H. Bryan; for Treasurer, Frank H. Pond; for Librarian, J. B. Johnson; for Directors, Robert Moore and T. J. Whitman.

The following nominations were made and duly seconded: T. D. Miller for Secretary, M. L. Holman for Treasurer, William Wise for President, George Burnet, Jr., for Vice-President, and Col. H. C. Moore for Director.

[*Adjourned.*] THOMAS D. MILLER, Secretary.

DECEMBER 16, 1885:—254th Meeting.—The club met at Mercantile Library at 8 P. M., President Moore in the chair, 22 Members and 1 visitor present.

Reading of the minutes of last meeting was postponed until they were printed.

The Executive Committee reported the acceptance of the resignation of Philip Buehner, of St. Louis. Jno. H. Kinealy was recommended for election as a member. He was balloted for and declared elected. The result of the canvass of ballots for officers for the ensuing year was announced as follows :

For President.—Robt. E. McMath, 77 ; Wm. Wise, 9.

For Vice-President.—Wm. B. Potter, 74 ; Geo. Burnet, Jr., 12.

For Secretary.—Wm. H. Bryan, 22 ; Thos. D. Miller, 63.

For Treasurer.—Frank H. Pond, 26 ; Minard L. Holman, 59.

For Librarian.—J. B. Johnson, 84 ; J. A. Siddon, 1.

For Directors.—Robt. Moore, 72 ; Thos. J. Whitman, 75 ; Henry C Moore, 22.

The President then declared Robt. E. McMath, President ; Wm. B. Potter, Vice-President ; Thos. D. Miller, Secretary ; Minard L. Holman, Treasurer ; J. B. Johnson, Librarian ; Robt. Moore and Thos. J. Whitman, Directors, as duly elected.

The newly elected President took the chair.

Retiring President Moore delivered an appropriate address.

Thos. D. Miller read a paper on "The Louisville Cements," which was generally discussed.

[*Adjourned.*] THOS. D. MILLER, Secretary.

DECEMBER 30, 1885 :—255th Meeting.—Club met at 8:15 P. M., at Mercantile Library, President McMath in the chair, 15 Members and one visitor present.

Minutes of last meeting were read and approved.

The Executive Committee reported the acceptance of the resignation of Thos. Featherson to date from Jan. 1, 1885 ; that Theo. Allen, being delinquent for dues for the year 1884, was considered as having resigned, and given four weeks to discharge dues for 1884–1885 and be reinstated ; O. A. Orrman, having failed to pay his initiation fee and dues for current year within thirty days, his right to membership was forfeited ; Geo. E. Otis and R. S. Hays were recommended for election. They were balloted for and elected.

The following amendment to Section 2 of the By-Laws was presented by the Committee :

"The annual dues shall be, for resident members four dollars, and for non-resident members, fifty cents in addition to the price of the JOURNAL."

Moved and seconded that the Executive Committee be instructed to investigate and report at the next meeting the advisability and cost of securing the services of a stenographer for the meetings of the Club.

The Committee reported that countersigned receipts would be issued to the Treasurer.

Prof. J. B. Johnson presented a paper to be read by title, "The Adjustment of a Quadrilateral."

The Secretary read a letter from Mr. Wm. T. Blunt, Sec. Ex. Board of Temporary Civil Engineers' Committee on National Public Works, also one from L. E. Cooley, President of that board.

Moved and seconded that a standing committee consisting of five members of this Club be elected to consider and report upon such questions as relate to the conduct of our national public work, and to act in conjunction with similar committees of other societies. Carried.

Moved and seconded that nominations be made and votes be taken for five, and the five receiving the highest number be declared elected. Carried.

Moved and seconded that the committee elect their own officers. Carried.

The following gentlemen were nominated, and the ballot resulted as follows:

R. E. McMath	13
Rob. Moore	13
J. B. Johnson	9
J. A. Ockerson	9
C. M. Woodward	7
M. L. Holman	8
T. J. Whitman	4
O. L. Petitdidier	2
J. A. Seddon	2
J. B. Eads	2
H. C. Moore	2
T. T. Johnston	2
Flad	1

Messrs. McMath, R. Moore, J. B. Johnson, Holman and Ockerson were then declared as constituting that committee.

Resolved, That the standing committee just elected be entitled the Standing Committee on National Public Works, and that its chairman be a full member of the Civil Engineers' Committee on National Public Works as suggested by the Cleveland Convention, but no action of this Committee shall be held as binding this Club until it shall have been reported to and endorsed by the Club.

Moved and seconded that the conclusions of the Cleveland Convention be referred to the Standing Committee to report at next meeting of the Club. Carried.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JANUARY, 5, 1886:—The 220th meeting was held at 7:30 P. M., Mr. Cregier in the chair.

The minutes of the preceding meeting were read and approved. The Secretary read a letter from President Williams, from New York City, regretting his inability to be present.

Mr. Charles E. Billin and Mr. Maurice Seifert were elected members.

Application for membership was presented from Mr. William S. Grant-Synn, Engineer Chicago West Division Railway, indorsed by Messrs. Wright, Cregier and Morehouse.

Mr. Cooley, for the Committee on the Organization of the Engineer Service for the Conduct of the Public Works of the United States, reported at length, recommending that "in place of the present Committee a permanent Committee on National Public Works be appointed, whose chairman shall be a member of the Civil Engineers' Committee on National Public Works."

The Annual Report of the Secretary was read, accepted and adopted.

Officers were elected as follows:

President, A. W. Wright.

1st Vice-President, C. H. Hudson.

2d Vice-President, D. J. Whittemore.

Secretary, L. P. Morehouse.

Treasurer, Charles Fitzsimons.

Librarian, G. A. M. Liljencrantz.

Trustees, S. G. Artingstall, A. Gottlieb.

A vote of thanks was tendered to the Association of County Surveyors and Civil Engineers of Indiana, for an invitation to attend the Sixth Annual Meeting at Indianapolis, January 19.

President Wright took the chair, introduced by Mr. Cregier, and made a brief address.

The Committee Report presented by Mr. Cooley was taken up for discussion. Mr. Cooley read a paper (to be printed), and after a full discussion the recommendation of the Report was adopted.

A bill of $30 for expenses incurred by the Committee was ordered paid.

At request of Mr. Irish, the general interests of the Society were informally discussed. It was understood that the Board of Trustees should give this matter consideration.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1885.

During the year twenty meetings have been held. A resolution of the Society lately adopted, declaring that it is expedient to abandon the meeting heretofore held on the third Tuesday of the month, will hereafter limit the yearly number to twelve. The hour of meeting has also been changed from 4 to 7:30 P. M., in deference to the views of some members who thought a larger attendance could be had at a later hour.

Thirteen papers have been read, as follows:

What Civilization Owes to the Architect and Engineer, by G. R. Bramhall.
Ventilation of Stables, by A. W. Wright.
The Separate *vs.* the Combined System of Sewerage, by Benezette Williams.
Some New Sewer Formulæ, by R. Frank Hartford.
The Best Material for Street Railroad Rails, by A. W. Wright.
An American Literature Society, by J. A. S. Waddell.
Ventilation of Buildings, by R. Frank Hartford.
The Water-Power of Niagara Falls, by Samuel McElroy.
Railroad Oracles, by H. B. Mason.
Amount of Horse-Power Used in Propelling Street Cars, by A. W. Wright.
The Relative Expenses of Some Items of Operating Upon Narrow and Broad-Gauge Railroads, by C. H. Hudson.
The Feasibility of an Inverted Siphon Tunnel for Improving the Water-Power of the Illinois River at Marseilles, by E. G. Ward.
Descriptive Experiments to Determine Frictional Resistance of Railway Trains, by C. H. Hudson.

The following named gentlemen have become members: C. P. Matlack, City Engineer, San Antonio, Texas; R. E. Brownell, Town Engineer, Lake, Ill.; J. M. Howells, City Engineer, Richmond, Ind.; Hiero B. Herr, U. S. Civil Engineer, Chicago; John W. Alvord, Town Engineer, Lake View, Ill,; A. Gottlieb, Consulting Engineer, Chicago; B. Schreiner, City Engineer, Des Moines, Ia.; G. L. Clausen, Assistant Engineer, Hyde Park, Ill.; Henry B. Chichester, Civil Engineer, Chicago.

In the spring a change of quarters was made, partly with the view of reducing our expenses for rent, and partly to enable us to co-operate with the Western Association of Architects and other kindred societies in establishing and maintaining more commodious rooms than any one Society could support alone. Another year will probably demonstrate whether or not it be desirable to continue our joint occupation of such quarters or to maintain rooms exclusively for our own use.

Receipts and expenditures are shown in the financial exhibit below:

Cash on hand at last report, in hands of Treasurer		$ 12 84
Received from entrance fees	$ 90 00	
Annual dues	779 80	
		869 80
Total		882 64
Paid for rent and moving	252 97	
Library	56 75	
Printing	68 75	
Postage, stationery and mailing	86 19	
New furniture	21 30	
Journal	353 00	
Total		$838 96
Balance in hands of Treasurer		43 68

L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

OCTOBER 5, 1885 :—Regular meeting held. Mr. Rundlett occupied the chair, and 16 members were present.

Mr. C. L. Annan was elected Member of the Society.

Mr. Truesdell then read a paper on the "Seventh Street Viaduct," after which he gave a very full and detailed description of the mode of doing the work and the cutting of the stone, illustrating his remarks with the original drawings of the work. On motion, Mr. Truesdell's paper was ordered printed.

The report of the Committee on the "Relationship of Civil to Military Engineers" was submitted. After debate it was amended and passed.

Mr. H. E. Stevens was elected delegate to the Cleveland Convention.

On motion, Mr. Loweth's subject for debate was postponed to the next regular meeting, and also the consideration of the report of the Committee on Constitution and By-Laws.

The meeting then adjourned to the first Monday in November.

C. J. A. MORRIS, Secretary.

NOVEMBER 2, 1885 :—Regular monthly meeting, eight members present. No business was transacted except an informal discussion on the subject of the relation of civil to army engineers, and regarding the proposed meeting in Cleveland.

On November 28 a special meeting was called and Mr. C. F. Loweth was elected delegate to the Cleveland Convention, in place of H. E. Stevins, resigned. The Secretary was directed to notify Mr. Blunt, Secretary of the Committee on Relation of Civil to Army Engineers, of Mr. Loweth's appointment.

[*Adjourned.*] C. J. A. MORRIS, Secretary.

DECEMBER 21, 1885 :—Regular meeting of the Society, Mr. Rundlett in the chair, 12 members present.

The minutes of the last meeting were read and approved.

Communications from Secretary Wm. T. Blunt, of the Executive Board of the temporary Civil Engineers' Committee on National Public Works, were read, requesting that action be taken by the Society with a view of appointing a permanent committee on National Public Works, and of expressing an opinion on the proceedings of the late Convention held in Cleveland the 3d, 4th and 5th of December, 1885. Also a communication announcing that the Cleveland Club adopted the action of said Convention, and continued its committee on National Public Works.

A communication from Mr. Newell, a Member of this Society, regarding permanent quarters for the Society, was read.

All the above communications were ordered laid on the table until the reports of the committees on the several subjects could be heard. On motion, the report of the Committee on Constitution and By-Laws was taken up for consideration.

Mr. Davenport was appointed as Committee on Incorporation ; after which the constitution and by-laws were read in sections, corrected and duly adopted.

A preliminary report of the Committee on Rooms was made, but no definite results having been reached, the committee was continued, with the addition of Mr. Rundlett as a member.

Mr. A. O. Powell's application for membership was read by the Secretary, and a vote was ordered to be taken on said application at the next regular meeting.

Mr. Lewis' resignation was read by the Secretary, and on motion accepted, all his dues being paid.

Mr. Loweth, as delegate and committee to the Cleveland Convention, gave a verbal report on the proceedings of said Convention, etc., but owing to the lateness

of the hour and the importance of the subject, no action was taken. It was ordered that the report of the proceedings of said Cleveland Convention be made the subject of special attention and consideration at the next meeting.

[*Adjourned.*] C. J. A. MORRIS, Secretary.

JANUARY 4, 1886:—Meeting called to order at 8 o'clock P. M., President Rundlett in the chair, ten members present. Minutes of last regular meeting read and approved.

Mr. A. O. Powell was duly elected a Member of this Society.

Communication from Wm. T. Blunt, Secretary of the Executive Board of the Civil Engineers' Committee on National Public Works, was read in regard to an early consideration of the action of the Cleveland Convention. The report of the Committee on Permanent Quarters was heard and the Committee continued.

The action of the Cleveland Convention of Civil Engineers, was then taken up and discussed by the Members of the Society, and the report of its delegate to the Society and the action of the Convention approved. The Society then elected Messrs. Charles F. Loweth, C. J. A. Morris and Wm. H. Wood a committee on National Public Works. Upon motion the Society then proceeded with the election of officers for the ensuing year, with the following result:

C. J. A. Morris, President; Charles F. Loweth, Vice-President; George L. Wilson, Secretary; J. H. Morrison, Treasurer; Wm. H. Wood, Librarian; H. A. Swenson, Auditor; C. J. A. Morris, representative of the Society on the Board of Managers of the Association of Engineering Societies.

The election of officers having been completed, the following By-Law was formally presented by Mr. Loweth to be considered at the next regular meeting.

At the regular meeting next following the Annual Meeting the President shall appoint such standing committees, to serve for one year, as the Government shall deem advisable.

[*Adjourned.*] GEORGE L. WILSON, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. February, 1886. No. 4.

THE DISTRIBUTION SYSTEM OF THE BOSTON WATER WORKS.

BY DEXTER BRACKETT, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 20, 1885.]

SOURCES OF SUPPLY.

Boston receives its water supply from three sources, Lake Cochituate Sudbury River and Mystic Lake. The original works, drawing their supply from Lake Cochituate, were built in 1848: they consisted of a conduit 14.6 miles in length, conveying the water from the lake to the Brookline distributing reservoir, whose surface is 124 feet above high tide, from whence it was distributed by cast-iron pipes throughout the city.

In 1869 the Chestnut Hill distributing reservoir was added to the system, and in 1872, as the supply furnished by Lake Cochituate was inadequate, the Sudbury River was taken as an additional source of supply. The waters of this river are collected in four storage reservoirs, having a combined capacity of about three billion gallons, or 120 days' supply, and conveyed to the Chestnut Hill reservoir in an independent conduit 16 miles in length. In the Chestnut Hill and Brookline reservoirs the waters from the two sources mingle, and the works unite in one system of supply and distributing mains 384 miles in length, from which are drawn an average of 25 million gallons per day.

By the annexation of the city of Charlestown the city of Boston acquired possession of the Mystic water-works, which were built in 1863-64. These works consist of a conduit 7,450 feet in length, conveying the water from Mystic Lake, the source of supply, to pumping machinery by which it is raised to a distributing reservoir of 26,000,000 gallons capacity, whose high water level is 147 feet above high tide. These works supply 6,210,000 gallons daily to the cities of Chelsea and

Somerville, the town of Everett and the Charlestown district of Boston, through a distribution system 120 miles in length.

MYSTIC DISTRIBUTION SYSTEM.

The distribution systems of the cities of Somerville and Chelsea and the town of Everett are owned and maintained by those municipalities. The details of the Charlestown distribution system are similar to those of the Sudbury and Cochituate works except in the material used for street mains. The entire distribution system of these works was originally composed of wrought-iron and cement pipe, but in Charlestown the greater portion of this pipe has been replaced by cast-iron pipe since the works have been annexed to the Boston system. The wrought-iron and cement pipe is composed of a thin sheet of wrought-iron riveted into a pipe and lined with cement mortar. The pipe when laid in the ground is incased in a coating of cement mortar, which, with the inner lining, is supposed to preserve the iron from corrosion. The experience in the majority of cases where this pipe has been used shows that the cement does not prove a protection, and that in from 10 to 15 years after the pipe has been laid the iron is destroyed and the pipe useless. During the year 1876, about 12 years after these pipes were laid, the number of bursts in Charlestown was one for each half mile of pipe in use, while on the Cochituate works, where the mains of cast iron had been in use for 28 years, the corresponding number was one for each 24.5 miles. In the city of Somerville twenty-nine breaks or bursts occurred in the wrought-iron and cement pipes during the month of September, 1884.

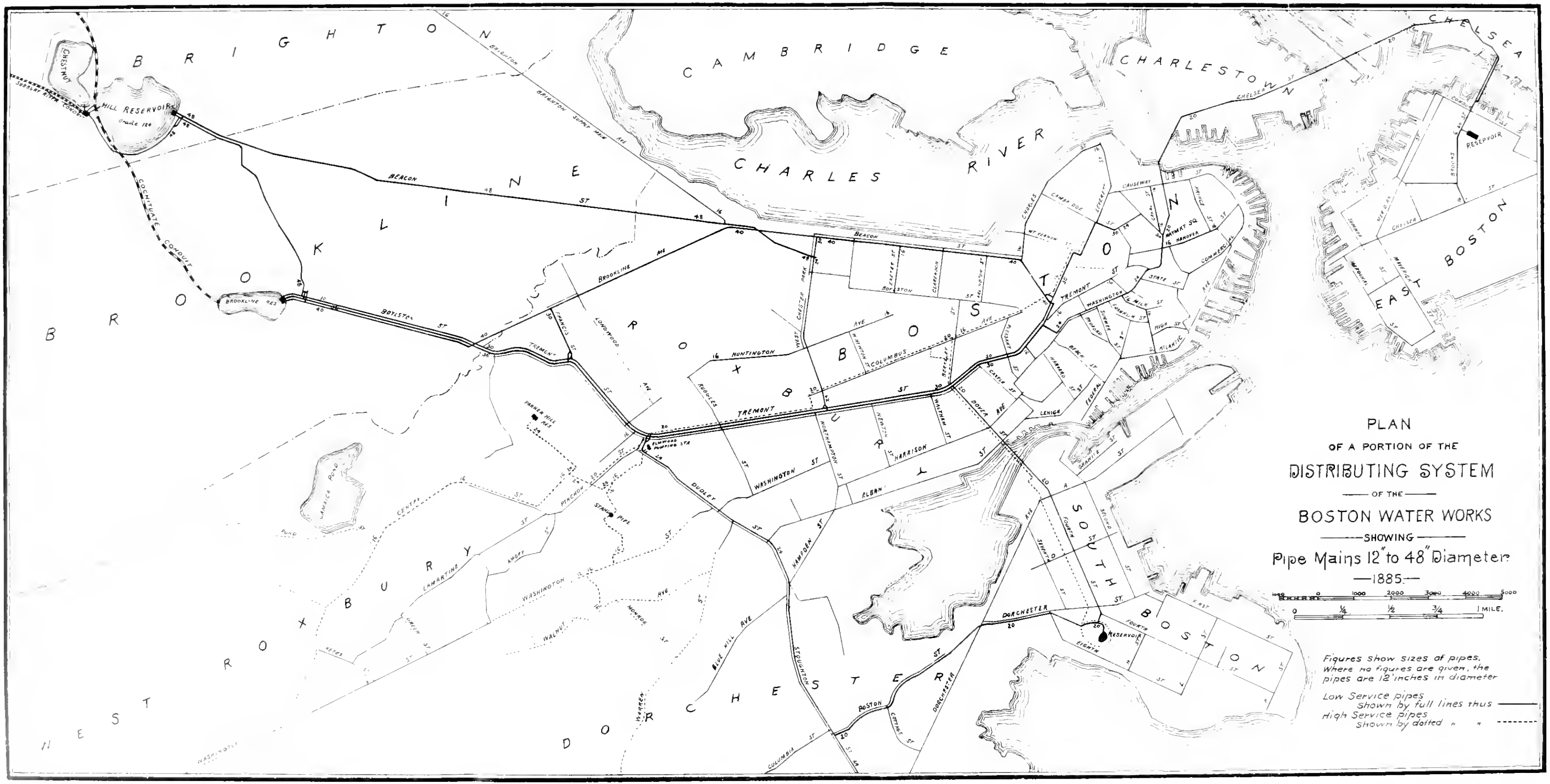
SUDBURY AND COCHITUATE DISTRIBUTION SYSTEM.

See Plate 1.

The water of the Sudbury and Cochituate supplies is conveyed from the Brookline and Chestnut Hill reservoirs to the city by four supply mains, 30 inches, 36 inches, 40 inches and 48 inches in diameter. These mains are so connected that the city's supply may be taken from either reservoir, or, if desired, the supply can be drawn directly from either of the conduits without passing through the reservoirs. The 30-inch and 36-inch mains from Brookline reservoir, laid in 1848, pass through Boylston and Tremont streets, a distance of 4.3 miles, to Boston Common.

The 40-inch main, laid in 1859, follows the route of the 30-inch and 36-inch mains to Brookline village, and continues to the city by way of Brookline avenue and Beacon street, connecting with the 30 and 36-inch mains on the Common at a point nearly opposite Mason street.

In 1880 a 48-inch main was laid from Chestnut Hill reservoir by way of Beacon street to Brookline avenue, there connecting with the 40-inch main. This 48-inch main was in 1883 extended through Commonwealth avenue to West Chester Park and connected by a 24-inch main in West Chester Park with the 30-inch and 36 inch mains in Tremont street, and by a 30-inch main with the 40-inch main in Beacon street. There is also a 48-inch main connecting the Chestnut Hill reservoir with the 40-inch, 36-inch and 30-inch mains near the Brookline reservoir, and a 30-inch main in Francis street, connecting the 40-inch with the 36-inch and 30-inch mains. A 24-inch main, 14,800 feet in


PLAN
OF A PORTION OF THE
DISTRIBUTING SYSTEM
OF THE
BOSTON WATER WORKS
SHOWING
Pipe Mains 12" to 48" Diameter
1885.
1000 0 1000 2000 3000 4000 5000
0 1/4 1/2 3/4 1 MILE.
Figures show sizes of pipes. Where no figures are given, the pipes are 12 inches in diameter
Low Service pipes shown by full lines thus
High Service pipes shown by dotted " "
BRIGHTON
BROOKLINE
CAMBRIDGE
CHARLES RIVER
CHARLESTOWN
CHELSEA
BOSTON
EAST BOSTON
SOUTH BOSTON
ROXBURY
WEST ROXBURY
DORCHESTER
CHESTNUT HILL RESERVOIR
BROOKLINE RES.
PARKER HILL RES.
ELMWOOD PUMPING STA.
STAND PIPE
RESERVOIR
SUDBURY RIVER CONDUIT
COCHITUATE CONDUIT
BRIGHTON SUPPLY MAIN
JAMAICA POND
BEACON ST
BOYLSTON ST
TREMONT ST
WASHINGTON ST
HUNTINGTON
COLUMBUS AVE
DUDLEY ST
DORCHESTER AVE
BLUE HILL AVE
BOSTON ST

length, branches from the 30-inch and 36-inch mains at Pynchon street in Roxbury, and passes through the Roxbury and Dorchester districts. At Dover street a 20-inch main, 8,570 feet long, branches from the 36-inch main for the supply of South Boston. A 30-inch main connects at Boylston street, and reducing to 24-inch at Washington street, passes through Washington, Union, Merrimack and Chardon streets to Bowdoin square, where it connects with a 30-inch main which continues on from the connection on the Common, over Beacon Hill by way of Joy, Mt. Vernon, Hancock and Cambridge streets. At Haymarket square a 20-inch main is connected with the 24-inch for the supply of East Boston. This main, 17,230 feet in length, passes the draw openings of the Charles and My tic rivers by means of inverted siphons, and the channel of Chelsea Creek by two parallel lines of flexible jointed pipes, each about 580 feet in length.

From these supply mains the network of 340 miles of distributing mains from 4 inches to 16 inches in diameter draw their supply. The length of the different sizes of distribution mains is as follows:

Size.	Length.		Percentage of total length.
16 inches.	9.4	miles.	3.0
12 "	104.6	"	30.7
10 "	3.1	"	1.0
8 "	34.3	"	10.0
6 "	162.0	"	47.5
4 "	26.6	"	7.8
Totals............	340.0	"	100.0

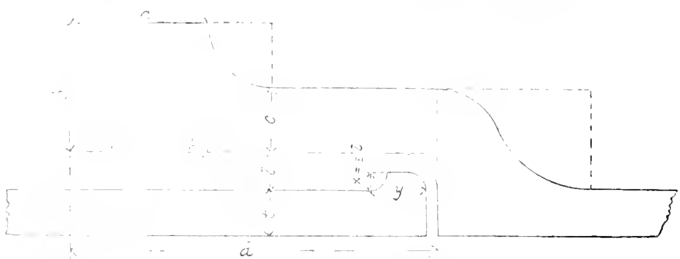
Since the year 1872 no pipe has been used for street mains of less than 6 inches diameter except in short and narrow courts where fire hydrants are not placed: and large quantities of 4 and 6-inch pipes have been replaced by mains of increased diameter.

The general plan of the distribution system is to have 12-inch mains at intervals of from 1,000 to 1,500 feet, with 6-inch and 8-inch mains in the intermediate streets. Throughout the business portion of the city the 12-inch mains are more frequent, and the district covered by the great fire of 1872 is now almost entirely piped with 16-inch, 12-inch and 8-inch mains. The quantity of distribution pipe of small size is less than in most of the large cities of the country: thus Philadelphia has 30 per cent. of her distribution less than 6 inches in diameter; Cincinnati, 58 per cent.: Chicago, 30 per cent.: Louisville, 49 per cent.; Baltimore, 70 per cent.: while Boston has only 7.8 per cent.

The material used for pipe mains has always been cast iron. All pipes laid since 1868 have been coated with coal tar by Dr. Angus Smith's process, and although this coating does not form a complete protection against the formation of tubercles, it very much retards their growth. Trials lately made show that the 6-inch uncoated pipes which were laid when the works were constructed have become so filled with tuberculations that they will not now deliver more than one-quarter of the quantity which a clean pipe will furnish, and are consequently of insufficient capacity for fire supply. The following table shows the standard thickness, weights, dimensions of sockets, etc., of the different sizes at present used.

WEIGHTS AND DIMENSIONS OF CAST-IRON WATER PIPES, BOSTON WATER-WORKS.

Diameter, in.	Class.	Dimensions in Inches.						Total length		Total wt. of pipes.	Wt. per running foot laid.
		a	*b*	*c*	*d*	*t*	*l*	Ft.	In.	Lbs	Lbs.
4	B	1.50	1.30	0.65	4.0	0.45	0.40	12	4	260	21.7
6	B	1.50	1.40	0.70	4.0	0.50	0.40	12	4	418	34.8
8	B	1.50	1.50	0.75	4.0	0.55	0.40	12	4	601	50.1
10	B	1.50	1.60	0.80	4.5	0.60	0.40	12	4½	815	67.9
12	A	1.70	1.60	0.80	4.5	0.58	0.40	12	4½	935	77.9
12	B	1.50	1.70	0.85	4.5	0.65	0.40	12	4½	1,050	87.5
16	A	1.75	1.70	0.85	5.0	0.66	0.50	12	5	1,413	117.7
16	B	1.75	1.90	0.95	5.0	0.75	0.50	12	5	1,615	134.6
20	A	1.75	1.90	0.95	5.0	0.73	0.50	12	5	1,945	162.1
20	B	1.75	1.90	0.95	5.0	0.85	0.50	12	5	2,252	187.7
24	A	2.00	2.10	1.05	5.0	0.81	0.50	12	5	2,588	215.7
24	B	2.00	2.10	1.05	5.0	0.94	0.50	12	5	2,985	248.8
30	A	2.00	2.30	1.15	5.0	0.93	0.50	12	5	3,690	307.5
30	B	2.00	2.30	1.15	5.0	1.10	0.50	12	5	4,336	361.3
36	A	2.00	2.50	1.25	5.0	1.04	0.50	12	5	4,929	410.7
36	B	2.00	2.50	1.25	5.0	1.25	0.50	12	5	5,882	490.2
40	A	2.00	2.70	1.35	5.0	1.12	0.50	12	5	5,897	491.4
40	B	2.00	2.70	1.35	5.0	1.35	0.50	12	5	7,055	587.9
48		2.00	2.70	1.25	4.0	1.00	0.50	12	4	6,266	522.1
48		2.00	3.00	1.70	5.5	1.25	0.50	12	5½	7,917	659.7
60		2.25	3.40	1.70	6.0	1.375	0.50	12	6	10,959	913.2



n = for 4-inch, 6-inch and 8-inch pipes 0.6 inch.
" 10-inch and 12-inch " 0.8 "
" larger sizes " 0.85 "

The weight of iron taken at .2604 lbs. per cubic inch.

The thickness is calculated by the formula $t = 0.0048\, n\, d + 0.35$, in which t = thickness of pipe in inches, d = diameter of pipe in inches and n = head in feet divided by 33.

The special castings used are designed to be of as compact a form as is consistent with convenience of manufacture and use, and the avoidance of excessive friction in the flow of water.

One special casting which may be worthy of mention is the form of Y branch shown on Plate 2, Fig. 9. This differs radically from the ordinary form of Y branch, the body of this branch being globular in shape. Failures of the old forms of Y branches have occurred, but none of this pattern have to my knowledge given any trouble. The largest size in use on the Boston works is 48 inches in diameter.

All pipe laying is done by day labor and as the work is done in short sections in different parts of the city, it cannot be done as economi-

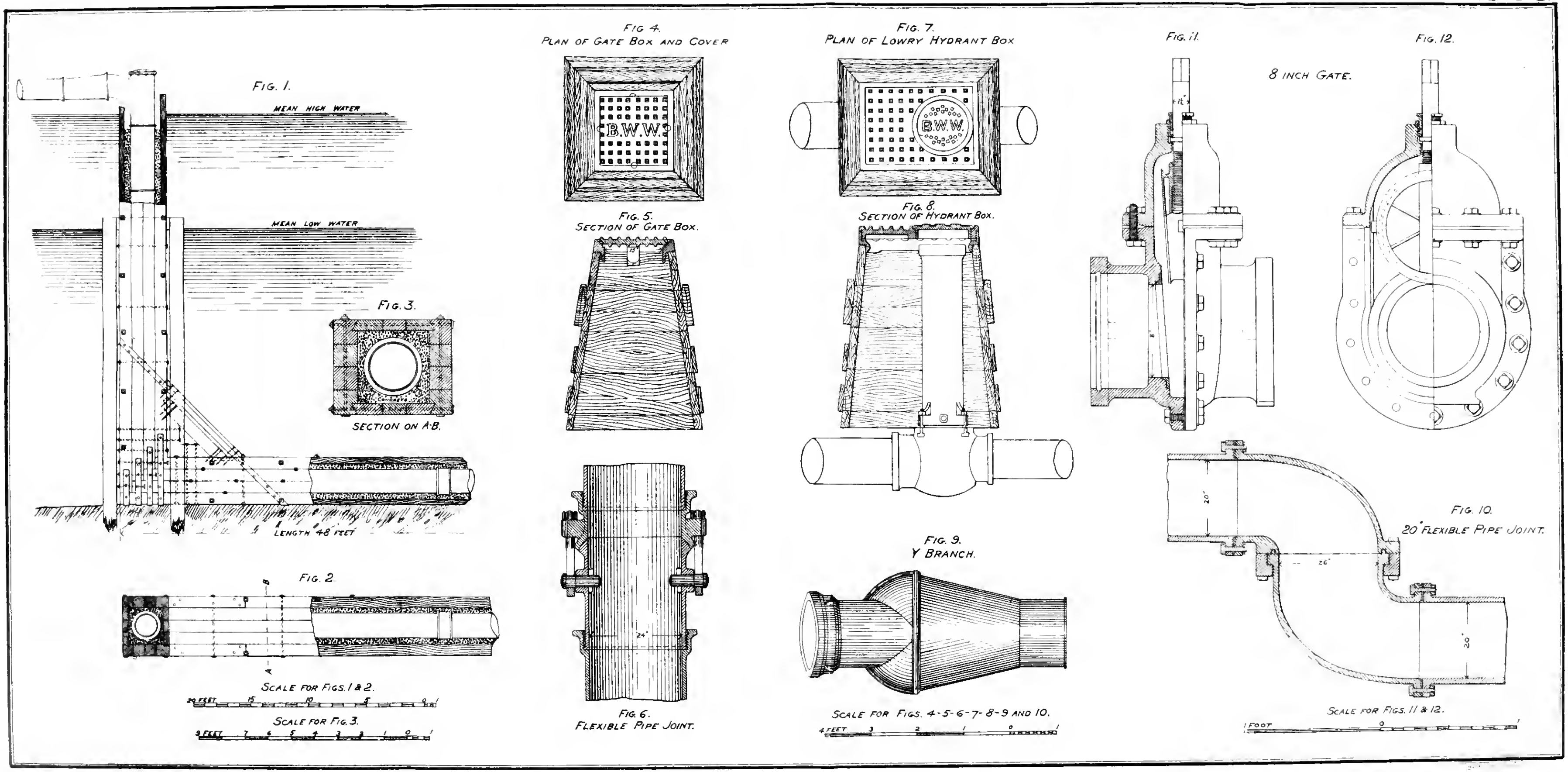


FIG. 1.
MEAN HIGH WATER
MEAN LOW WATER
LENGTH 48 FEET
FIG. 3.
CONCRETE
SECTION ON A-B.
FIG. 2
A
B
SCALE FOR FIGS. 1 & 2.
20 FEET 15 10 5 0 1
SCALE FOR FIG. 3.
8 FEET 7 6 5 4 3 2 1 0 1
FIG 4.
PLAN OF GATE BOX AND COVER
B.W.W.
FIG. 5.
SECTION OF GATE BOX.
FIG. 6.
FLEXIBLE PIPE JOINT.
24"
FIG. 7.
PLAN OF LOWRY HYDRANT BOX
B.W.W.
FIG. 8.
SECTION OF HYDRANT BOX.
FIG. 9.
Y BRANCH.
SCALE FOR FIGS. 4-5-6-7-8-9 AND 10.
4 FEET 3 2 1 0 1
FIG. 11.
8 INCH GATE.
FIG. 12.
FIG. 10.
20" FLEXIBLE PIPE JOINT.
20"
26"
20"
SCALE FOR FIGS. 11 & 12.
1 FOOT 0 1

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cally as in constructing an entire system of distribution. The present cost of laying the smaller sizes of pipe is as follows:

	Cost per lineal foot				
	4 inch.	6 inch.	8 inch.	12 inch.	16 inch.
Pipe and special castings..........	$0.38	$0.57	$0.83	$1.27	$1.87
Lead, gasket, blocking, etc..........	.05	.06	.08	.12	.17
Teaming..........	.02	.03	.05	.07	.08
Labor, trenching and laying..........	.25	.27	.30	.37	.45
	$0.70	$0.93	$1.26	$1.83	$2.57

Pipe, 1½c. per pound. Labor, $2.00 per day.

The cost of gates and hydrants for the above sizes is approximately 15 cents per lineal foot of pipe. The centres of the pipes are placed 5 feet below the surface of the roadway, and generally at a distance from the street line of about one-third of the total width of the street. The pipe joints are composed of hemp gasket and lead, the lead being about 1¼ inches in depth and thoroughly calked. The quantity of lead required for different sizes of pipes can be expressed by the formula $l = 2d$, in which l = pounds of lead per joint and d = diameter of pipe in inches, and as the pipes are usually 12 feet in length, the quantity of lead required per lineal foot of pipe equals one-sixth of the diameter of the pipe in inches.

At many points throughout the city the pipes are carried over railroads and water courses or under navigable streams. The crossings are made in different ways: in some cases the mains are supported by independent structures of wood or iron, and in others they rest directly on the bridge floors. Some of the large supply mains are directly exposed to the weather, others are surrounded by a single boxing, while some of the distributing mains in exposed situations are inclosed in a double boxing. In no case is any packing used to protect the pipes as it has been found by experience that a confined air space affords the best protection, on account of the liability of the packing to become wet either from leakages into the box or from the pipe joints. Where the mains cross navigable streams, the channels are passed either by inverted siphons or by flexible jointed pipe. The construction of one of the inverted siphons is shown on Plate 2, Figs. 1, 2, 3. An iron pipe of extra weight is inclosed in a box constructed of heavy timbers strongly bolted and strapped together, the space between the pipe and the inside of the box being filled with cement concrete.

The supply main to East Boston crosses Chelsea Creek by two mains, 20 inches and 24 inches in diameter, each about 580 feet in length, laid side by side in trenches dredged to receive them.

Fig. 10, Plate 2, shows the joint used in the original line laid in 1850. These joints turn on a leather packing, which is placed in the groove between the flanges, and are flexible only in a vertical plane. They are 31.25 feet apart, connected by three pieces of 20-inch flanged pipe, one and one-half inches in thickness. The diameter of the pipe is increased at the joints to compensate for the increased friction at the bends. This pipe was prepared on a staging, and lowered by tackles into the trench, which was then filled with gravel and clay. The 24-inch main, laid in 1871, by G. H. Norman, has a turned ball and socket joint, flexible only in a vertical plane (Plate 2, Fig. 6). The joints are 26 feet

apart, connected by two lengths of ordinary bell and spigot pipe. This line, 650 feet in length, was put together on the shore, buoyed by empty barrels, towed into position and sunk by cutting the barrel lashings. A number of leaks have occurred on these submarine pipes, but with one exception they have been caused by starting of the lead packing, and have been easily repaired by a diver. The largest leak was caused by a crack about eighteen inches in length, in one of the flanged pipes of the 20-inch line. This leak was repaired by wooden wedges driven into the crack and covered by a rubber band, the whole being held in position by iron bands and clamps. The supply for the public institutions on Deer Island crosses Shirley Gut, a channel 400 fee wide and 37 feet deep, by two lines of 8-inch pipe, having Ward's patent flexible ball and socket joints. The current at this point is very rapid, and instead of laying the pipe from a float-stage they were joined together on the shore and drawn across the channel by means of a windlass placed on the opposite shore.

GATES AND HYDRANTS

To control the flow of water in the mains there are in use 3,932 gates, or about one for each 500 feet of pipe. These gates are of various patterns: some of the older ones have valves which are kept closed by the pressure of the water; others, made by the Boston Machine Company, have adjustable wedge valves, while the pattern used at present has a solid wedge valve. An 8-inch gate of the present pattern is shown by Figs. 11 and 12, Plate 2. All gates used on the works are made from our own designs, and sizes below 20 inch are manufactured at our own shops. The hydrants set previous to the year 1868 are of the pattern shown by Fig. 7, Plate 3; they have barrels but 3 inches in diameter, and are supplied by a branch pipe, from the main, 4 inches in diameter. Most of these hydrants have been in use from 25 to 35 years, and their capacity (originally small) has been greatly reduced by tuberculations. They also require constant attention during the winter season to prevent their being frozen, owing to the valve being but 3½ feet below the surface of the street. For these reasons they are gradually being replaced by hydrants of larger capacity. One thousand five hundred of them, however, still remain in use. When the distribution system was extended into Roxbury, after the annexation of that city in 1868, the Lowry hydrant (Figs. 3 and 5, Plate 3) was introduced. This hydrant has a 9-inch barrel, which is placed directly over the distribution main, and in many cases at the intersection of mains, so that it is capable of furnishing a very large supply of water, and by means of a portable casting called a "chuck" (Fig. 3), four steam fire engines can be supplied from each hydrant. Difficulty was experienced with this hydrant on account of the power required to open the valve, owing to its large area. The pattern now used has a smaller valve opening upward (Plate 3, Fig. 4), and the original large valves have been fitted with a small supplementary valve, which being opened fills the hydrant and relieves the pressure on the main valve (Plate 3, Fig. 6). The cost of maintaining this hydrant is large on account of its location in the roadway, and, except where it is desired to mass a number of steamers, a smaller hydrant located in the sidewalk

PLATE 3.

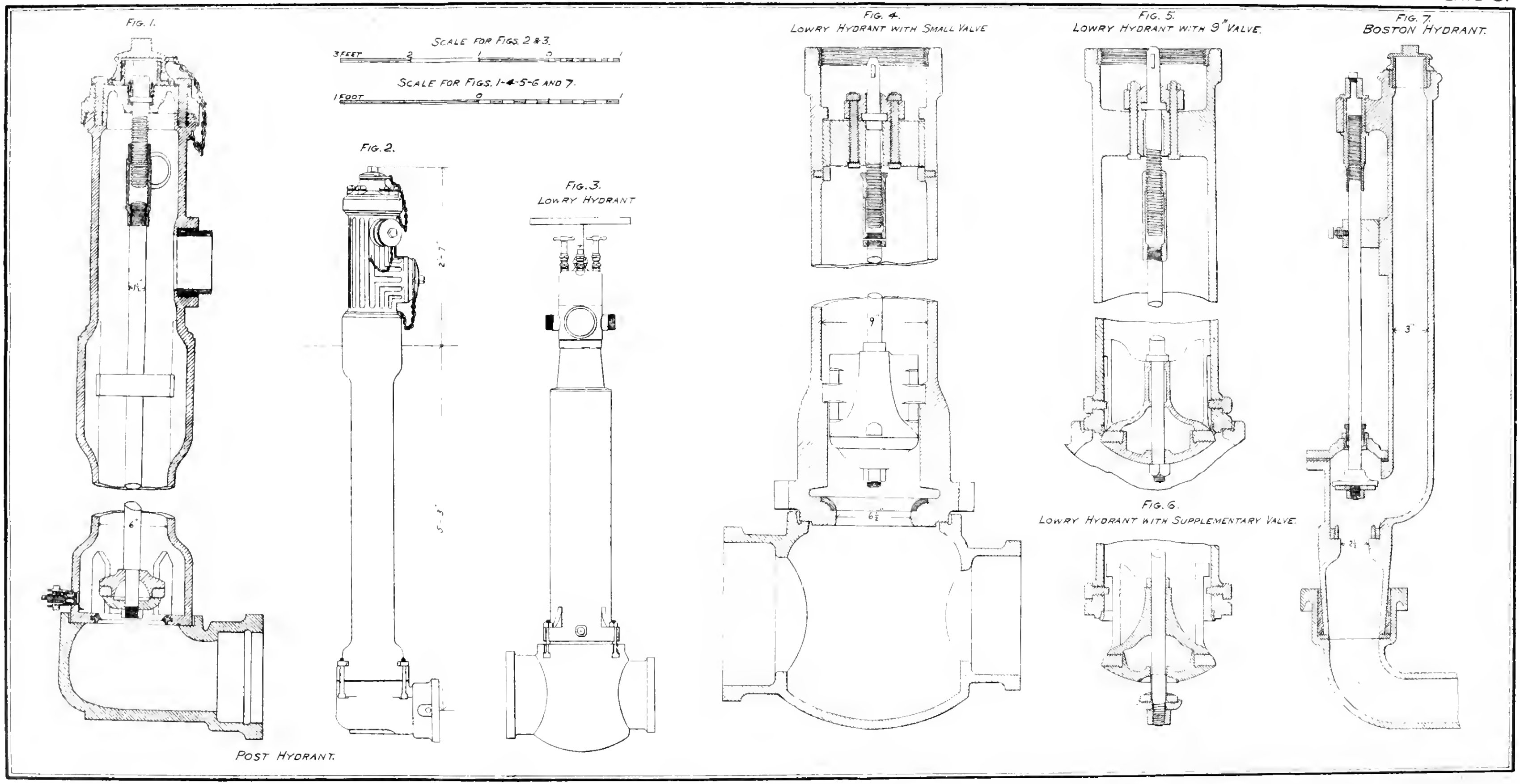


FIG. 1.
SCALE FOR FIGS. 2 & 3.
3 FEET 2 1 0 1
SCALE FOR FIGS. 1-4-5-6 AND 7.
1 FOOT 0 1
FIG. 2.
2'-7"
5'-3"
FIG. 3.
LOWRY HYDRANT
FIG. 4.
LOWRY HYDRANT WITH SMALL VALVE
9"
6½"
FIG. 5.
LOWRY HYDRANT WITH 9" VALVE.
FIG. 6.
LOWRY HYDRANT WITH SUPPLEMENTARY VALVE.
FIG. 7.
BOSTON HYDRANT.
3"
2½"
6"
POST HYDRANT.

is to be preferred. The sidewalk hydrants now used are of two patterns. The Post hydrant (Plate 3, Figs. 1 and 2) has a 6-inch barrel, and is used in the outlying districts and in sections of the city where the sidewalks are of sufficient width to permit of its use without annoyance to public travel. The other hydrant, which is placed in or under the sidewalk (not shown on plate), has a 6-inch barrel or valve similar to the Post hydrant, and a top adapted to receive the Lowry chuck. Both of these hydrants are connected with the street mains by 6-inch pipes. Both hydrants and gates are inclosed by wooden boxes of sufficient size to be entered for the purpose of repairs. These boxes are of the general form and construction as shown by Plate 2, Figs. 4, 5, 7, 8, and for the past 10 years they have been made of kyanized spruce lumber. The average life of these boxes, as determined by records kept since 1850, has been about 15 years; and as the cost of the box, with its iron frame and cover, is only about $8, the wooden box is, without doubt, cheaper than one of iron, if it is desired to have the boxes large enough to be entered.

SERVICE PIPES.

Between forty and fifty thousand service pipes convey the water from the distributing mains to the premises of the water takers. These service pipes are, with a few exceptions, of lead, and are generally of $\frac{5}{8}$-inch internal diameter, weighing 2.75 pounds per lineal foot. During the original construction of the works, some services of cast iron $1\frac{1}{2}$ inches in diameter were used; most of these have been removed, but some still remain after 35 years' service. The question of the danger to public health from the use of lead service pipes was very carefully investigated in 1848 by Prof. Horsford, and the conclusion reached at that time was that the Cochituate water might be served from leaden pipes without detriment to health. I think that it is now generally accepted as a fact that the water of most of our fresh water ponds and rivers forms on the surface of lead an impervious compound which prevents further action of the water on the pipe. The service pipes are all laid by and at the expense of the city from the street mains to a point three feet beyond the street line.

From 1848, when the works were constructed, until 1879, the only stop-cock for shutting off the water from the buildings was inserted in the main, and was reached by means of an iron tube whose top was covered by a loose cap from 6 to 12 inches below the surface of the street (Plate 4, Fig. 1). This method was adopted to prevent the operation of the stop cocks by unauthorized persons, but much trouble was experienced in reaching the cocks in cold weather, or under concreted streets, and for the past five years an additional stop-cock has been placed in the sidewalk and made accessible by a telescopic tube shown on Plate 4, Fig. 1. Until the year 1863 all of the service-cocks were driven into a hole drilled in the iron main, and this method is still in use in some cities. In Boston, however, all of the cocks are screwed into the mains without shutting off the water. This is done by means of the machine shown on Plate 5, Figs. 1, 2, 3, an invention of Mr. E. R. Jones, the present superintendent of the distribution system of the Cochituate works. The machine consists of the composition chamber *A* containing

the valve *B*. To the end of the chamber *A* is attached the head *C*, through which passes the spindle *D*, which is worked by the ratchet-lever *E*. The chamber *A* is clamped to the pipe, as shown in the figure, the same machine fitting pipes of different sizes by means of rubber gaskets of the proper radius: a drill is attached to the spindle *D*, and a hole drilled through the main; the drill is then withdrawn, the valve *B* closed, the head *C* removed and the drill exchanged for a tap. After the hole has been tapped, the stop-cock is attached to the spindle and inserted in the main, completing the operation. The time required to insert a stop-cock is ordinarily about ten minutes, but it can be done in six minutes.

A new form of stop-cock to be used in place of the ordinary form of sidewalk stop-cock has lately been adopted by the Water Board. Three hundred of these are now in use, and it is intended to place them on all of the services throughout the city. This stop-cock, shown on Plate 4, Figs. 2 to 8, is known as the Church stop-cock or waste detector, as in addition to the usual functions of a stop-cock it can be used to detect and determine the amount of water which may be wasting from a service-pipe to which it is applied. In addition to the usual water passage, there is in this stop-cock a small supplementary passage *A*, through the plug, which, by means of the tube *B*, can be connected with a pressure gauge attached to the top of the tube. When the plug of the stop-cock is turned to a certain position the water passes from the street main through the small orifice *A* to the gauge and indicates the water pressure in the main. Now, if the plug is turned to the position shown in Figs. 5 and 6, water will pass through the small orifice into the house, and if there is any leakage taking place from the house fixtures, the pressure on the gauge will at once fall; the amount of the loss of pressure being dependent on the quantity wasting. A third position of the cock connects the gauge with the house service, closing the connection with the street main, and if the leak in the house be at a point 23 feet above the gauge the pressure will fall to 10 pounds and there remain, showing the height above the gauge that the leak may be found.

Very small leaks can be detected, a loss of pressure of one pound indicating a waste of 15 gallons per hour. In detecting waste by means of these stop-cocks an examination of all the service-pipes in any street is made in the manner just described, between the hours of midnight and four A. M., when all legitimate use of water is supposed to have ceased, and the premises where waste is noted are examined on the following day, and the causes of waste discovered and remedied.

Three years ago I had the pleasure of presenting to this Society a description of some experiments made in the Charlestown district with the Deacon waste-water meter (see Vol. I., p. 253–266, of the JOURNAL of the Association). As a result of those experiments, the system has been adopted for the whole Sudbury and Cochituate works, and can now be considered a permanent portion of the distribution system. Sixty-eight of these meters, controlling a population of about 320,000 people, have now been in use for about a year, and the results obtained by their use fully confirm the reports of the previous experiments. The meter has been improved by a reduction in size with an increase in capacity, and is

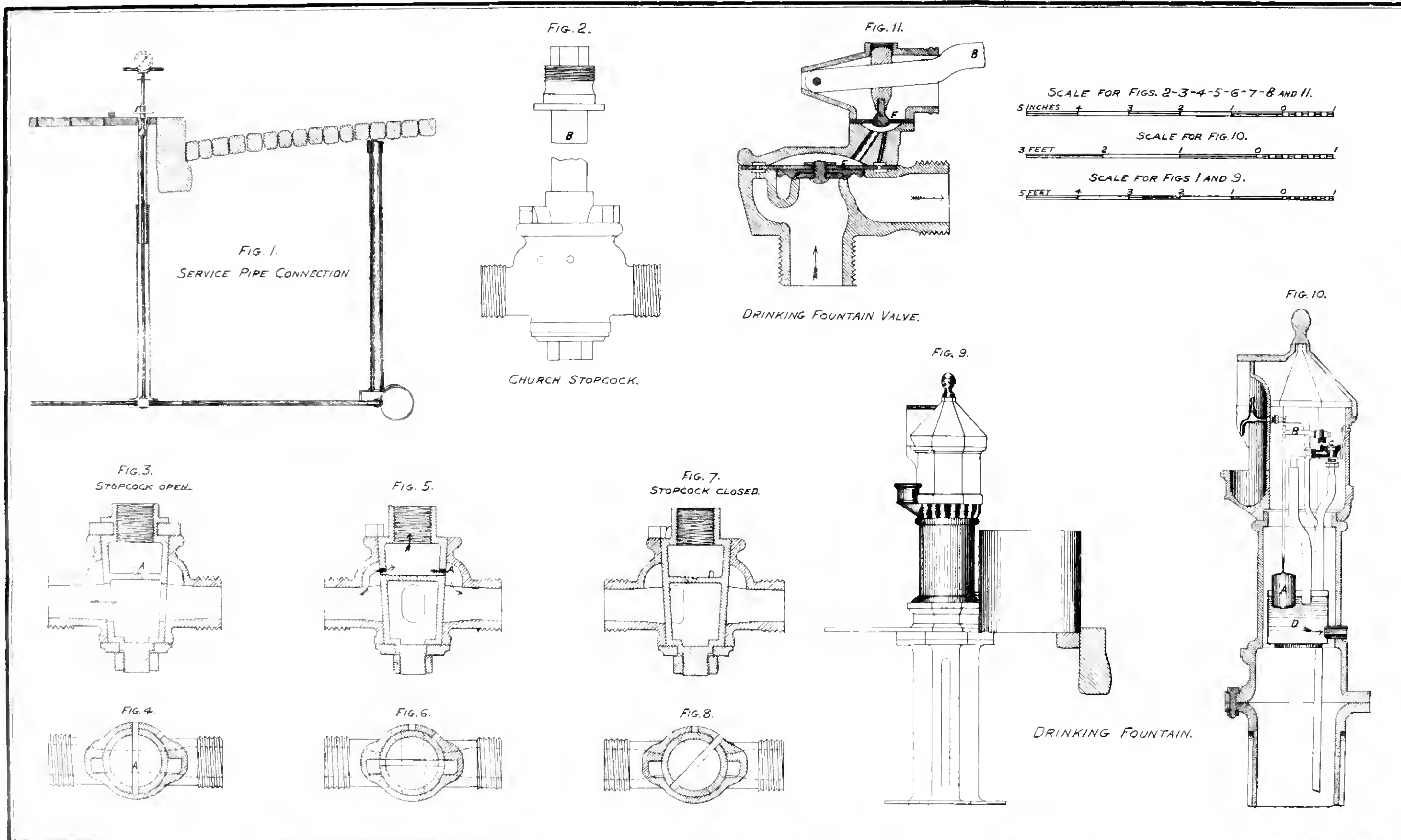


FIG. 1.
SERVICE PIPE CONNECTION
FIG. 2.
B
CHURCH STOPCOCK.
FIG. 11.
B
F
E
DRINKING FOUNTAIN VALVE.
SCALE FOR FIGS. 2-3-4-5-6-7-8 AND 11.
5 INCHES 4 3 2 1 0 1
SCALE FOR FIG. 10.
3 FEET 2 1 0 1
SCALE FOR FIGS 1 AND 9.
5 FEET 4 3 2 1 0 1
FIG. 3.
STOPCOCK OPEN.
A
FIG. 5.
A
FIG. 7.
STOPCOCK CLOSED.
FIG. 4.
A
FIG. 6.
FIG. 8.
FIG. 9.
FIG. 10.
B
C
A
D
DRINKING FOUNTAIN.

FIG. 2.

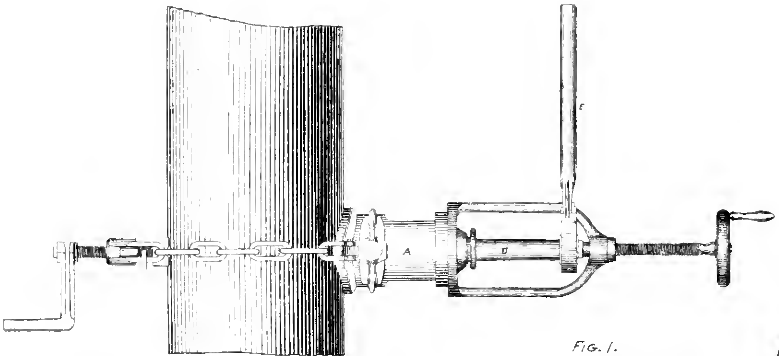


FIG. 1.
JONE'S TAPPING MACHINE.

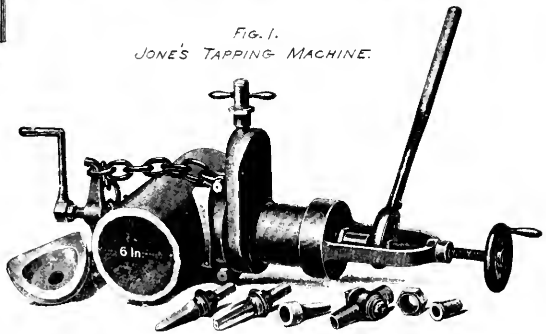
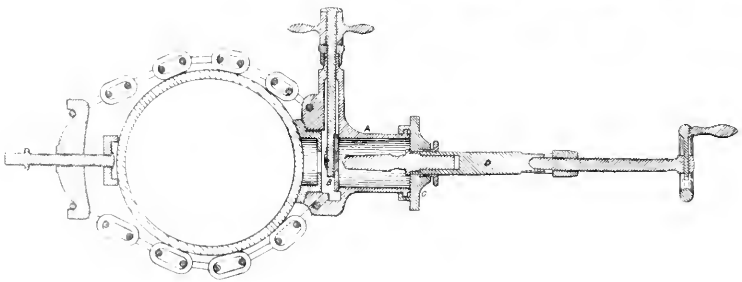


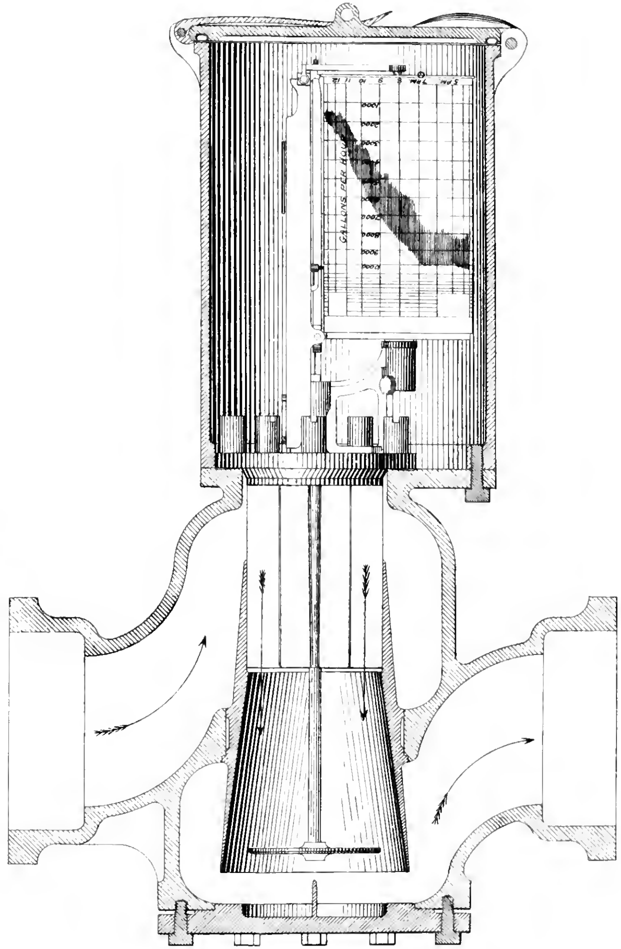
FIG. 3.



SCALE FOR FIGS. 2 AND 3.

1 FOOT 0 1

FIG. 4.
DEACON WASTE WATER METER.



SCALE FOR FIG. 4.

1 FOOT 0 1

HELIOTYPE PRINTING CO. BOSTON.

shown in its present form by Fig. 4, Plate 5. The meters are all placed on a by-pass under the sidewalk, and so arranged that they can be shut off and the working parts of the meter removed during the winter season. The total cost of the 6-inch meters, including cost of setting, is about $600 each. The daily average consumption of the Sudbury and Cochituate works for the year 1881 was 8,630,200 gallons, or 21.6 per cent. less than for the previous year, although the records of the meters show that there still remains a large amount of waste in some sections of the city. The great advantage gained by the use of this system of waste detection is the ability to localize the sections in which waste exists, and thus avoid the annoyance and expense of inspection in sections where the water fixtures, services and mains are in good repair. During the past year a number of leaks have been discovered in the main pipes and services, from which the water had been running from one to ten years, and from which it would probably have continued to run but for the use of these meters. A few weeks ago an unused service-pipe was found which had been discharging between 1,500 and 2,000 gallons per hour into a drain for at least ten years.

Figs. 9, 10 and 11, Plate 4, show the pattern of public drinking fountain in use. The trough for the uses of horses is of granite, and the supply of water is controlled by the valve *C* (Figs. 10 and 11) so that there is no waste of water from the trough. The valve is operated by the float *A* acting through the lever *B*. When the trough is full the lever *B* is in the position shown by Fig. 11, the small valve *F* is closed, and the diaphragm valve *E* is kept closed by the pressure of the water on its upper surface. If the water in the trough be lowered the float *A* drops, the valve *F* is opened and the pressure on the valve *E* being relieved, that valve at once opens to its full capacity, and so remains until the valve *F* is again closed, when the pressure of the street main being brought on the top of the valve *E* it is immediately closed. The valve is operated by a very small change of level in the trough.

WATER METERS.

The policy upon which the works are at present managed is to control the waste of the residential portions of the city by means of the Deacon and Church waste detectors, and to apply recording meters throughout the business and manufacturing sections. With this end in view the number of recording meters has been largely increased during the past few years, and at the present time 4,959 services, or about 10 per cent. of the total number, are metered. The number and pattern of meters in use is as follows:

Worthington	1,231
Crown	1,222
Tremont	2,479
Other patterns	27
	4,959

RAILROAD ORACLES.

By Henry B. Mason, Member of the Western Society of Engineers.

[Read October 6, 1885.]

Railroad oracles are usually very reticent, and when they do say anything it is apt to be some misleading "point," which induces the hearer to embark his hard-earned and scanty surplus into speculation and loss. Away goes the money which was to have papered his house, to have clothed his wife with a black silk dress and himself with a stylish coat, and to have given both husband and wife a vacation at the seashore. The loser spends the summer in the city, his trousers bag in the knee, his faded carpets do service for another year, and he smiles grimly when he hears that Vanderbilt has erected a four million dollar residence.

But not long ago I happened to find a railroad oracle in a genial and loquacious mood. Several reasons accounted for this unwonted frame of mind. He had made many thousands of dollars recently and saw hundreds of thousands and even millions in the near future. I did not wish to speculate, and he did not care to have me, and we met merely upon the plane of good fellowship. Although he was much older than I was, an hereditary friendship existed between us. In earlier days and more primitive scenes, his mother and mine had lived together, and the girlish friendship continued as long as his mother lived. Such were some of the influences which tended to make the oracle communicative. Then I paid him the sincere attention of an interested listener. He was a good talker; he could do great things and tell about them, too. Metaphorically, he carried both sword and trumpet. We met in the lull after a busy day. It was late afternoon.

Before telling his story, let me present the man to the Engineers' Club. Please imagine then a figure of gigantic height, certainly more than six feet and a half high, of broad shoulders and naturally of large bulk, though somewhat reduced by the anxieties of great undertakings; a head suggesting a lion; an engaging smile, but lips which occasionally straightened into a severe, determined line. On account of his physical and financial size he had a way of treating his fellow men as though they were boys, yet so pleasant was his manner that you felt you could hardly resent it even if he should address you as "Bub." This large man was seated at ease in a cushioned arm-chair, and thus discoursed :

A scheme was started in 1872 to build a railroad from a point in Ohio to the city of Chicago. There were nine or ten men in the enterprise. They procured a charter, made a slight survey, gained some right of way and laid a few miles of track with light iron. Then the panic occurred and stopped work, leaving the company in debt to contractors and officers. A corporate organization was kept up, however, in hopes of better times. At the annual meetings the scattered projectors came together again and tried to devise means for carrying out the original plan. The dusty map was unrolled where a railroad straight as the bird flies had been depicted running through paper cities. At the sight hope revived. Corner lots, terminal facilities, through freights and county aid

bonds were the cheerful topics of conversation. Each wizened speculator in his shiny coat became in imagination a railroad magnate in broadcloth. The directors stalked from their board meeting with a dignity which slowly faded away during the next twelve months of farming, clerking, petty litigation, and so on, to which they were severally obliged to resort for a living pending the realization of the railroad project: but was rejuvenated at each recurring annual session. Nine years passed. They had tried to get money in New York, but had not succeeded. The few miles of rail rusted, and the ties rotted away. Nobody but wild ducks met at the projected junctions; prairie chickens nested at unrealized way-stations, and cattle grazed on the sites of anticipated cities, unconscious that the prairie beneath them had been subdivided on maps and labeled "court-house," "church," "academy," and "depot." The world plunged its branding iron into the hottest fire and stamped the enterprise a failure.

A discouraged remnant of the directors invited the railroad oracle to meet them at their annual session in 1881, to see if he would help them get the requisite money and would then take contract to build the road. At this meeting he listened to all that was said, jotted down the schedule of old indebtedness, which was due mostly to the projectors themselves for services and advances or had their guaranty, scrutinized each speaker keenly, but maintained an oracular silence until he had reached his own conclusions. Toward the end of the meeting he had weighed the project and the projectors in his mental scales and saw in the scheme itself greater possibilities than its originators had imagined. They looked anxiously toward him for his decision. He towered above them on the vantage ground of physical size, wealth, good clothes and superior executive ability, and from this rostrum now made a short incisive speech, like Xenophon's addresses to the ten thousand or Napoleon's army bulletins: "Well, gentlemen, it appears to me you have not done much in nine years, when this railroad ought to have been built in eighteen months. I do not wish to associate with you collectively; luck is against you, if nothing else. If you want to clear out of this project and sell it to me for the amount of the indebtedness, I will agree to assume and pay this indebtedness, with liberty to fight some claims, and you give me a bond that the total indebtedness shall not exceed eighty thousand dollars. I shall pick out some of you to help me in the reorganized enterprise, but will have nothing to do with you in a lump." These words of fate were a surprise to the listeners. Here was a Titan, who could dig gold in Wall street and iron in the Alleghanies to build and equip the railroad, but most of its originators were not to be allowed a seat in his triumphal car. The single voice ceased and a buzz of discussion followed. Modifications of the proposition were suggested to the railroad oracle, but in the significant language of the Orient to denote inexorable purpose by a single phrase, "He had spoken." Compelled to consider his terms without modification, some were favorable and some opposed; but the majority were disgusted with the road and voted to sell out, and finally all concurred, for each one hoped to be employed in the new organization and now tried to recommend himself by a cheerful acquiescence

in the transfer. Everything was turned over to him, the plant, charter, right of way, stock, and bonds. Certificates making up all the shares of stock were assigned to him by the projectors, and the bonds were handed to him in the original packages as they came from the engraver, for the public had never invested in the road. He put in his own board of directors, choosing two or three of the original projectors, two or three New York capitalists, and some relatives of his own, giving each one just enough stock to qualify him for the position. The enterprise, though corporate in form, was really swayed by his single mind, presenting a fine example of concentrated power and divided responsibility. The two or three original projectors still in the board were too happy at being included in the new organization to make any resistance to him, and had they done so he would have voted them out at short notice. Besides, he had selected them for their qualities as trusty lieutenants, and they recognized him as their chief. The New York capitalists had simply lent him their names, and were naturally less solicitous about the matter than if they had loaned him any money. His relatives he had of course selected for personal fidelity. Under his direction the stockholders and directors met, passed some cut-and-dried resolutions, elected his brother president of the company, his brother-in-law treasurer, and his cousin attorney, and adjourned. That was all he needed of them for the present. Then he spent thirty thousand dollars for thorough surveys, testing different routes in the general direction of the proposed road. The first visible evidence of this expenditure was sticks in the ground, geometrical drawings and columns of figures; but it was amply justified, in the result, by the singular freedom of the chosen route from deep cuttings, high embankments and long bridges. He was thus involved one hundred and ten thousand dollars, however, before he had any assurances, other than his own inner consciousness, that he could make the project pay; but he knew a fact, worth a million dollars, that a great trunk line was threatened with a loss of its Chicago connection. The trunk line proper ended about two hundred miles from Chicago and ran its cars over a leased road into our city. The lease would expire in a year or two, and some rival influence was thwarting attempts for its extension. The loss of the Chicago connection would degrade the trunk line into a mere local road, curtail earnings, change the cheerful ledger heading "Surplus" into that gloomy account "Deficit," cut off dividends and endanger interest on bonds, so that its very existence was at stake. Accordingly my narrator called upon the president of the trunk line at an auspicious moment for the plan, which he unfolded in these words: "I want to give you a through connection with Chicago and don't want any money from you." The president, surprised and pleased by the beginning and conclusion of this statement, was prepossessed in favor of the scheme and listened with interest to its details. My narrator's proposition was simply: "You give me as much of your western bound freight transportation as I give you freight going east." The proposed contract had the simplicity of most great plans. Its reciprocity feature recommended it for adoption. It would insure the new road much business and thus

help to give it the necessary credit for selling construction bonds and it would enable the old road to hold its own against rivals. The president of the trunk line made minute inquiries and was pleased with the thoroughness of the surveys, the easy grades, eligible town sites, area under cultivation, and short distance to Chicago. He suggested that a combination of established roads might not allow the new enterprise a fair share of freight, but my narrator replied that he proposed to carry freight low for a year and thus force a recognition by competition. The momentous interview resulted in an acceptance of the proposition, and articles of agreement were executed accordingly. This document and the standing of the railroad oracle gave the necessary credit for selling construction bonds, but no very advantageous offers were made at first, and an enormous bonus was demanded in stock and profits of construction, which the railroad oracle felt a sturdy disinclination to give, and this reluctance had the good effect of making his securities an object of competition among leading New York bankers. He knew, of course, that every man who brings an enterprise into Wall street must divide, but wished to make this division out of the prospective premium on the bonds, and to keep the stock and profits of construction to himself. Ten million dollars in seven per cent. bonds were offered for sale. At this stage, the president of the trunk line, realizing the supreme importance of untrammeled access to the West, made an appointment with the railroad oracle, and frankly said, "My road wants control of the Chicago connection." "All right," replied the railroad oracle, "when it is built you can control it, but you must guarantee the bonds of the new road out of its gross earnings, and let me have everything that the road makes over and above expenses." Oriental diplomatists would have taken years to reach this plain understanding of each other's views. Each side had named its ultimatum, and both ultimata were embraced in the ingenious arrangement entered into. In the first place, the trunk line made the proposed guaranty. In the second place, three kinds of stock were issued. One kind, an issue of $9,000,000, represented power: it was voting stock. Each share gave its holder one vote, and a majority of these shares could elect directors, and through these agents appoint all officers and employés and control the road; but this stock was, under no circumstances, to receive dividends. The entire amount of simply voting stock was issued to the president of the trunk line as trustee for his road. Thus, the trunk line controlled its Chicago connection The second set of stock, called subsidiary stock and amounting to $10,000,000, meant wealth, for this stock was to participate in all dividends made: it did not, however, entitle its holder to any voice in the control or management of the road. The entire block of subsidiary stock was issued to the railroad oracle. Thus he was entitled to receive what the road made over and above its expenses. There was indeed a third variety of stock, being the ordinary kind, entitling its holders to vote and receive dividends. Counties through which the proposed road had to go had by this time subscribed for a million dollars of stock, and an issue of this amount was made in order to obtain the benefit of those subscriptions. It was arranged that the railroad oracle's board of directors were not to be dispossessed until the road should be

built. All foreseen contingencies were carefully provided for in a written document, but nevertheless there are possibilities of future litigation in these complicated ownerships, enough to thrill the heart of a corporation lawyer.

With the trunk line guaranty added to the traffic agreement there was no difficulty in disposing of the bonds advantageously. A New York syndicate agreed to take the whole issue at ninety-five cents on the dollar, and in ten days placed them in Amsterdam at a hundred and three. The railroad oracle had a finger in this pie and pulled out a plum, for he subscribed to five hundred of the bonds as a member of the syndicate and thus made $40,000 without paying a cent, but simply by his signature, a valuable autograph. The railroad oracle now took a partner to assist him in building the road, for a division of labor had become absolutely necessary, one man was required to attend to finance and the other to construction. The board of directors promptly awarded to the new firm the contract to build the road. The new firm were to receive as compensation all the proceeds of the bonds as sold at ninety-five. This entire amount in money had already been deposited in one of the New York trust companies, and was loaned on call at three per cent. upon United States securites. It was subject to the order of the president of the trunk line, who honored the contractor's drafts. It was arranged that the contractors should pay the interest on the bonds until the completion of the road. With bonds for ten million dollars drawing seven per cent., and their proceeds only yielding three, it is at once apparent what a frightful loss is sustained on interest account, and this seems at first blush to have been a blunder of the contractors. It was really wisdom, however, for the loss in interest was more than counterbalanced by the enormous advantage of buying everything for cash, by reason of the large discount allowed on such purchases. Moreover, the contractors were in the position to make advances to manufacturers in consideration of corresponding rebates. By reason of judicious advances at a period of temporary depression, rails only cost the contractors fifty-four dollars a ton, when worth sixty-two dollars; cars, tools, and so forth, in the same proportion. The work was prosecuted with speed and skill. Able assistants were employed at high salaries. The engineer received twelve thousand dollars a year. When the work of construction was under full headway, ten thousand dollars were disbursed every day. At the time of my interview the road was within a few months of completion, when it would form an indispensable link in a great railroad system, running from the prairies to tide-water. The railroad oracle expected to then retire to his ancestral farm in New Jersey with a greater treasure than was ever captured by Alaric or Attila.

I have not hitherto mentioned the railroad oracle's name, but an unexpected incident, to which I will shortly refer, now allows me to state, that under the name of railroad oracle, I have described John Condit Smith. Gray-headed men will recall the fact that he began business as a civil engineer in Illinois at the time of the building of the Illinois Central. Old soldiers will remember him as Sherman's quartermaster-general in the march to the sea. Men about town may recollect his towering

form at the Calumet Club three summers ago. The unexpected incident to which I have referred as allowing me some frankness of disclosure, was his death. It came suddenly in the hour of his triumph, when the railroad had been completed; and I count such demise glorious, like Wolfe's death on the Heights of Abraham, or Nelson's on the deck of his flagship.

FIRE-PROOF BUILDINGS.

By Theodore Rosenberg, Member of the Civil Engineers' Club of Cleveland.

[Read July 14, 1885.]

In laying the present paper before the Club, I must confess that I have attacked a problem that has been the study of many an able and practiced member of the profession; one which has formed the topic of good-rounded articles, pamphlets and books; a problem which has busied the minds of architects, engineers, builders, professional clubs, city authorities and the legislatures of States. The question is as modern looked at from one point, as its importance is evident and ancient.

It having become customary to speak of so-called fire-proof buildings (as if such a thing could be) as monuments to the ingenuity of recent inventors, it might be well to inquire as to the origin of the term. We all know that buildings strictly fire-proof—*i.e.*, buildings that are in each and every particle and detail of their construction so constituted as to not only resist effectually, but exclude by their very nature the possibility of the originating of a fire—would be untenable. Imagine a house built of say stone and nothing else, or exclusively of iron, with or without terra-cotta casings. Therefore, all that can be aimed at by building fire-proof so-called, would culminate in the one principle, that no matter what the different materials selected might be, their use should be determined upon in co-operation with the interior arrangement to such effect as to confine the fire once started to the inclosed location where it originated. But there are buildings of a peculiar kind which should be put up under certain rules, framed so as to cover all the points necessary to be observed and legally safe from any tampering therewith by iniquity, greed, and well or evil purposed ignorance.

But reverting to the classification of buildings, I would say that there are buildings whose purposes in themselves express the necessity of fire-protective construction. There are hospitals, asylums for the infirm and mentally deranged, factories, assembly rooms of any kind, if confined to peculiar surroundings, churches, theatres, barracks, hotels, jails, office blocks and public buildings, as court-houses, libraries and schools. Now, the very considerable value of most of such structures should recommend their fire-protective construction. In fact most court-houses are in a measure constructed so. Some of our hospitals would need looking after in that respect, and as to some office blocks in the heart of the business part of our city, most of us know on what deficient principles they have been built, and how the means of egress have not been provided for in number, quality and location. Our theatres—well this is a point that

might well form the contents of a book, and might with all detailed description show only part of the many mistakes made, the wanton negligence, the ignorance displayed, and in some instances the basest motives that have actuated their owners when planning their construction. No blame for this falls upon the profession. I am proud to state that no architect of standing would lend himself to carry out a plan resembling some of these death-traps—monuments of iniquity that I wish might be razed to the ground—a lasting shame to the memory of their originators. Imagine a theatre hemmed in on two, and in some instances, on three sides by buildings of equal height, with thin brick walls surrounding them filled with material of the most inflammable character, with inadequate means of egress, occupied by a full audience. Imagine such a theatre on fire: nay, imagine but the effect even a false alarm would produce. There is one of those hells right here in this city, and do what you will in the way of providing fire-escapes, you will never be able to dissuade me from predicting a holocaust that will probably resemble those of Vienna and Nice, or outdo them, if but for the sake of transatlantic superiority.

One need be no cynic to view the results of the Chicago fire in the light of the tendency prevailing in that city to build in a substantial and fire-protective manner, but *it is* a sad fact that we acquire wisdom by bitter experience that sometimes might be spared to us by the exercise of sound reason and judgment in proper time.

The means to construct reasonable protection from fire have been but insufficiently employed in most instances, because of their supposed cost. The arrangement of the interior might in some cases set at naught the very costliest construction, consisting in heavy rolled beams and girders, incased in one and two shells of terra cotta. I mention, for instance, the danger arising from the faulty construction of an elevator, or else we might observe, as was the case at a recent fire in a fashionable apartment house in this city, a sufficient fire-protective construction everywhere but in the top story and roof, for—so it is explained—the walls were not strong enough to support a fire-safe roof. In some other instances it was observed that the very simplest means prevented fires from making further progress, and this in buildings full of combustible materials. No. 16 iron plates on both sides of a medium thick door protected a vast store of oils and paints from being burned; the iron was buckled, the wood scorched in some places, still the fire without did not penetrate the door, and considerable stores were saved. One-inch layers of plaster or mortar placed between joists on rough boards, and covered with asbestos felt, upon which the top floor rests, might be considered effectually fireproof; that is, they will withstand a fire from below until the engines arrive. Some might say that a fire-protective structure need not depend on the fire department; still, I have not heard of a case where the department was *not* called out in case a "fireproof" block caught fire. Even our frame houses might be rendered comparatively safe by intersecting the flues formed by the covered framing, by plastered or brick-bat-covered boards. The mode of shutting off the basement from the framing by bricking in from top of the foundation behind the sill to under side of floor, and in case of a braced frame, by bricking on top of

the dropped girt and top-plates, as well as plastering heavily, instead of deafening between floors, has grown in favor and has been frequently used of late. The latest novelty in more substantial buildings is the use of doweled boards forming arches, in place of brick or terra cotta around iron girders, which wood arches are honeycombed by iron encased in wooden plates, and a similar treatment to flat floors and ceilings, as well as the employment of wood-cased iron between studs, for which system great efficiency in the way of fire protection, durability, lightness, strength and cheapness is claimed. It has been patented by Architect Leo Staub, of Pittsburgh, and bids fair to win favor with the profession. The inventor uses for a combination of a waterproof floor and a fireproof ceiling matched, tongued and grooved flooring in one layer placed in the usual way, and a layer of surfaced boards laid diagonally and nailed to the joists. Between these two layers of boards are placed rectangular pieces of sheet lead, not lapped, but placed like flags and soldered together. The long spaces between joists are divided into compartments by the use of planed boards inclosing a layer of sheet metal. The ceiling below is formed in a similar manner, in reversed order, and the layer of metal between the boards is sheet-iron, cemented at the joists.

By screwing the two layers of floor and ceiling boards respectively together, the inventor claims to produce the desired effect in the best-known way. He furthermore makes mention of the comparative inefficiency of terra cotta and brick or mortar, and plaster covering of iron supports or girders, which offer not the most desirable protection against expansion of the inclosed metal by exposure to the fierce heat to which they are sometimes subjected. He also incloses iron columns by two layers of wood casings, plate metal, tightened diametrically by screws. In a like way compound columns, girders and whole trusses may be protected. Vaults for storage of valuables are constructed of five layers of boards and four layers of sheet metal between them, screwed together through the thickness of the whole casing and intermediate layers; the screws are being set into the wood and the set holes cemented. For a detailed description I refer to the supplement of No. 476, *American Architect* of February 7, 1885, from which I have gleaned the above notes.

That our terra cotta casings for iron structural parts are not always the surest protection against undue expansion and afterward cracking and bending of the iron, may be seen from Messrs. J. C. Buckle and A. E. Woodruff's comparative table of the value of different materials as conductors of heat, from which we see that

Slate = 1000	Dry oakwood = 336
Common brick = 660	Cement plaster = 200
Fire brick = 620	Plaster paris and lime = 225
Asphaltum = 451	Cast-iron = 11,000

in their respective value as conductors—and knowing that the greater the structural density of a material, the greater the value as a conductor of heat—the smaller that as a protector against heat is, we must conclude that the metals have as such no place in the class of fire-safe materials.

From this table we also see that such terra cotta casings—ranging with fire-brick—should be carefully plastered and finished in plaster of

paris. This is done with columns, but not always with ceilings and floors. Now wood, dried thoroughly, treated with a preservative and used in combination with iron, either in sheets where wood itself serves as a support, or combined with metal sheeting, to protect iron or independent wooden supports, or finally, wood combined with plate metal and cement gypsum, would appear to be as efficient a protective against fire as any other known combination, and preferable on account of the saving in cost. This should lead our building owners to the resoive to construct all those buildings, referred to previously, as safe from fire as possible. The question of cost—though certainly not a very important one—becomes with our present knowledge of the different materia's a secondary one, and it needs only the proper impetus given by the authorities to encourage the building of comparatively low eost and yet fire-safe buildings.

Where cost is from the start a secondary consideration, the so-called woodstone, an English patent, would seem to fill the bill in more than one instance.

The woodstone is a compound of sand, free clay and peat, mixed very thoroughly by machinery constructed for this purpose, and the mixture, after having been subjected to a pressure of several atmospheres, is dried artificially for about six days and afterwards burned 48 hours.

The woodstone ought to make a very desirable material for the construction of such parts of buildings as are designed to be light, and yet rigid and safe from fire. Besides claiming these qualities for his invention, the patentee describes the material as being only half as heavy as brick, but might be, according to the purpose for which it is intended to be used, made heavier or still lighter. Woodstone may be treated like brick or stone as regards bonding it by mortar or cement, with both of which it may be treated also surfacial, or it might be nailed, sawed, polished and painted in oil or al fresco with mural colors. It is said to be a poor conductor of heat, sound and electricity, and absolutely fire, water and acid-proof if properly treated, and may be also used as an insular-covering for underground wires or submarine cables, or in place of asbestos packing and covering for steam ducts. All it needs now is the feasibility of cutting it into large sheets for flies, soffits, wings and drop curtains, dress goods for actors and firemen, and the millennium of theatre building will have surely arrived.

A material resembling the woodstone somewhat, is the corkstone—a compound consisting of the remnants of cork stopper, manufactory clay and air-slaked lime, thoroughly mixed to a stiff paste, molded and air-dried. Its specific weight is 0.3, a single brick of the dimensions $2\frac{3}{8}$ in. $\times$ $4\frac{3}{4}$ in. $\times$ 10 in. weighing only $\frac{6}{10}$ of a pound. If plastered on both sides, these bricks are claimed to be indestructible by fire. They are used mostly on the Upper Rhine for roofing purposes in thin layers, and in normal size for partitions or unloaded arches.

Terra cotta wood, a patent of Mr. C. Gillman, of New York, if I am not mistaken, is mainly composed of kaolin and saw-dust. According to the desired degree of porosity, the mass contains from one to three imes as much kaolin as saw-dust ; it is then subjected to a strong pres-

sure, and the cylindrical blocks so obtained are first dried and then burned to a white heat. These blocks weigh not quite half as much as our common hard bricks; they are indestructible by fire, and may be treated like the wood-stone just described. I do not know, however, that they have been used practically to any extent. Our usual forms of hollow bricks from the Ohio River offer a sure protection from fire. Unfortunately, their use is confined to the filling in and forming flat arches between iron beams, the lower flanges of which are not sufficiently covered to prevent warping of the iron. A trial of these bricks inclosing wooden beams was made some three years ago in New York, and very satisfactory results were obtained. A fire burning fiercely for one hour did not even discolor the joists inclosed and covered by these hollow bricks.

After the many trials with a number of more or less meritorious protectives in the line of building materials and the contemplation of such frightful disasters as had happened in crowded buildings, more especially after the fire of the Vienna Ring Theatre some four years ago, a society was started, that had for its members some of the foremost architects and civil engineers of that city, and for its main purpose the contrivance of means by which to build a theatre as nearly fire-proof as possible. It seems that something has been done toward the realization of their purpose, for a theatre built according to the outline specifications furnished by that society shows a vast improvement over the prevailing style.

All the partitions in the whole house are built of strong hollow brick. Even the box compartments are treated thus. All the intricate machinery behind, above and under the stage, is run by water power. An immense proscenium wall separates the stage from the auditorium. The dress-circle and pit show for every tier of two rows of seats on each side of the main aisle, a separate exit into the foyer, running around the whole horseshoe-formed auditorium in abnormal width. This foyer is similar in each story. The wall between the foyer and the auditorium is double and its compartments formed by the doors and their jambs are used as ventilation flues.

The galleries do not rise one on top of the other, but are arranged in amphitheatrical form, so that each individual spectator may look at the stage from any point of the house. The exits for the galleries grow more numerous the higher they are situated. Stairways of easy rise and of ample width are provided everywhere, and doors are arranged to swing both ways. There are four stairways for each gallery, all straight, leading directly, without a turn, out of the building.

The ceiling is double, and is made of sheets of asbestos-covered iron, the lower one of which is perforated for ventilation purposes. Of course, all the dressing and living apartments, as well as storage, machinery rooms, etc., are treated with the same endeavor to prevent a fire as much as possible. Water-plugs are placed conspicuously in numerous places. The iron curtain works in two halves, resembling somewhat our sash balances. If not used, the proscenium opening is free. It is, however, ready for use, and one part coming down from a level above the opening pulls the lower part up, the upper edge of which

reaches to the lower line of the footlight gutter. The upper part has an extension hinged on its lower edge, which drops at the moment of the junction of the two main divisions, thus forming a double protection. This curtain runs sideways in a rigid frame, forming a vertical track, and is sufficiently strong to keep its place and resist the draft of a fire long enough to allow the house to be emptied in time. Next, it would be in place to mention an instance or two showing what unthought-of origin fires may have some time. I have it on good authority that the gas used for lighting purposes contains gasoline—that is, it enriches the gas, or, in other words, it is cheaper for the gas companies to use gasoline in common with coal for the purpose of manufacturing gas. Should such gas leak in greater quantities, the coal-gas would naturally rise to the highest part of the room, while the gasoline would remain below, and a casual ignition of the gas at the upper level would cause the vaporized gasoline to explode also. It is asserted that the Park Theatre fire could not have assumed such proportions as it did, but for this cause. The quantity of escaped gas was not great enough in itself to do as much damage as was done by the second explosion caused by the ignition of the gasoline. The shock was big enough to nearly burst the proscenium wall and move it bodily out of place. Two distinct explosions were observed: the first, the lower one, is said to have been comparatively insignificant; balls of fire were seen to fly about, and then after a distinct space of time, the second explosion took place. The indiscriminate handling of telephone and other electric wires may cause explosions and set fire to buildings, considered safe otherwise. I know of a fire in one of the fire engine stations in this city which was caused by concentrating a battery capacity designed to supply six circuits each of from five to seven miles long into one single circuit. In conclusion, I will say that a city of the size of Cleveland might well support a building bureau, or whatever other name you might want to give it, and without assuming to particularize the duties of such a department, I believe it would meet the approval of the profession and all rightly concerned in buildings.

Such a building bureau should have charge of the examination of all plans of contemplated buildings, additions, alterations, etc.; of filing the accepted ones by copies, and keeping records thereof, and should also be authorized to issue building certificates, all of which would give us valuable statistics of buildings in a city of one quarter of a million inhabitants, where hundreds of thousands of dollars are annually expended in building. I believe it would not be beyond the province of this Club to take the initiative step toward the creation of such a department.

SOME CONSIDERATIONS OF THE RELATION OF BED TO THE VARIABLES IN RIVER HYDRAULICS.

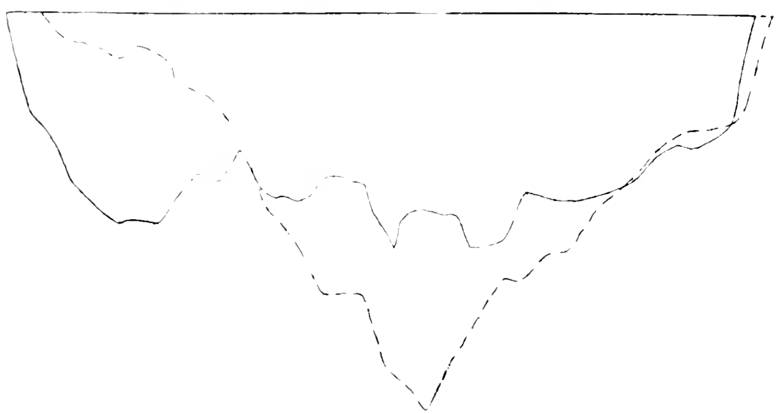
By James A. Seddon, Member of the Engineers' Club of St. Louis.

[Read January 6, 1886.]

It is of course unnecessary to call the attention of river engineers to the changeable character of cross-section in alluvial rivers. Among others, a valuable paper by Mr. McMath (See Report Mississippi River Commission, 1881, p. 212), has brought one phase of this subject prominently forward. It is thought, however, that the extent of this change is not realized by the general profession. The change here meant is not the difference between a cross-section at one point of the river and another at a different point, but the difference between the cross-section at the same point at different dates.

Simply as an illustration I have prepared two contrasted sections, pre-

PLATE A. Scales: Horizontal, 300 ft. = 1 inch. Vertical, 7.5 ft. = 1 inch.



sented on Plate A. It shows the difference in bottom for two determinations about four months apart, or the soundings are reduced to the same gauge height and plotted. This is not an extreme case at all, but is presented as about a fair example of the change that may be met with on the Missouri River. From this some definite idea can be got of how the bed of the river varies as a whole.

The phase of this variation, which has been before spoken of as having been brought prominently forward, is the effect of one cross-section on another. This is considering the interactions between different parts of the bed, and differs from that view which seeks the cause of a given condition of bed, considered as a whole. In other words, the cross-section has been regarded in the light of being itself a *cause* of certain changes: it is wished by the writer to consider it only as in itself an *effect* of certain forces.

That the nature of the relation between the effect and its cause may be discussed, the hydraulic term "Uniform Flow" will be defined and

used, and in its definition two other terms with special meanings "Energy" and "Resistance."

Energy—written "E"—will be used as the number of foot-pounds received from the action of gravity on the masses of water in a given length of stream during one second. Its value is $62.4\ Q\ H$; where Q is the number of cubic feet of water that flow through any of the cross-sections of the reach during one second, and H is the difference in height of water surface at the upper and lower ends of the given length of stream considered. 62.4, of course, is the weight of a cubic foot of water, and, being the constant factor for the units taken, will be regarded as understood, in the future, so that Energy will be written $E = Q\ H$. To make this equality perfectly clear, suppose we had a stream flowing with the constant discharge of 10 cubic feet per second: now, if we consider a length of 100 feet of this stream, having, say, a fall, or difference in the height of water surface at the two ends, of one foot, we see that during one second 10 cubic feet of water pass into this volume at the upper end, and 10 cubic feet pass out at the lower end with one foot lower potential energy, the volume of water in the length considered remaining the same: we may now see the equality stated above, that is, that the sum of all the particles of water into their elements of fall, during one second, in this 100 feet of stream, is equal to 10 cubic feet of water falling through one foot, or, as stated, $E = Q\ H$.

Resistance—written "R"—will be used in a strictly similar sense. It will be defined as the number of foot-pounds expended in friction in a given length of stream during one second.

It follows from these definitions, that considering energy and resistance for the same length of stream, we have the following relation between them: Resistance + the increase in kinetic energy or resistance + the energy stored in change of velocities through the reach = energy. Now "uniform flow" is defined as that condition of flow in which resistance = energy, in other words, all the energy given by gravity to the falling masses of water is expended in friction. This may be true for an element of length, or true for a reach of considerable length, taken as a whole, yet not true for the elements of that reach.

A word here in the way of elementary hydraulics. It is plain that in an open trough leading from a reservoir, uniform flow will be established at given distances from the reservoir for given inclinations of trough, and will continue indefinitely along the trough from the point where it commences; for up to this point energy is being stored in velocity or velocities are increasing. Experiment has also shown that resistance increases with some power of velocity; so that up to the point resistance is also increasing, and at the point $R = E$, and from thereon they are constant and equal. By seeing in this way that any difference between energy and resistance soon produce equality between the two, we come to the conclusion that generally a reach may be selected at any part of the river, which, taken as a whole, satisfies the conditions of uniform flow, though, unlike the trough, the elements of this reach may not satisfy the conditions. For such a reach then $E = R$.

Now E consists of two factors, the size of the river or Q, determined by its drainage basin, and the fall or H, in the main, determined by the

valley slope. These are perfectly independent variables, and it is seen that energy reaches its equality with resistance by the change of those conditions alone on which resistance depends. H is regarded as an independent variable because it is so in the line considered in this paper: it has, however, a dependent feature which assumes importance where bend development is to be considered.

One more step in this generalized reasoning, and we will pass to something more definite.

By the constant change of cross section the assumption is justified that the material composing the bed of an alluvial river is in a condition of strain that is close to the maximum strain that it can bear without movement. It almost goes without saying that a portion of the bed that has just stopped scouring has just reached the point where the friction of the water can no longer move it. This is, at first, not so apparent for a fill; in fact, there are certain kinds of fill where it is not true, an instance of which is the fill at the point of a reef. An eye study of this question, however, will show that fill in many cases cannot be distinguished from scour except by final effects, they both being an accompaniment of a general movement of material along the bed of the stream, and strain at any point above or below the maximum, producing in the one case the final effect of scour, in the other case fill. We, therefore, repeat that the material composing the bed of an alluvial river is in a condition of strain that is close to the maximum strain that it can bear without movement. For convenience, when this condition is exactly fulfilled—that is, when the strain is not close to the maximum, but is the maximum, it will be called bed or sections in equilibrium with the forces, or, more briefly, in equilibrium.

Now these strains in the material are the reactions of those forces which measure resistance. Assuming then that the bed of a stream is composed of one given material, that is, that this maximum strain is a constant, and that the condition that holds approximately in the alluvial river holds exactly in this stream, that is, that bed is in equilibrium with the forces, we conclude that a change of resistance can only accompany a change of bed. For brevity, this conclusion will be stated $R = f$ (bed), where a somewhat extended meaning of the term f is introduced. We have then in the case of uniform flow for an *element of length* $E = R$ or $Q\,H = f$ (cross-section).

A convenient way of seeing the bearing of this is in its contrast with the case of the trough mentioned before. For the trough, we might say that uniform flow was established for any slope by the change of velocities, while in the river it was established by change of cross-section, since in the river velocities were constrained in some way by the bed's ability to bear them.

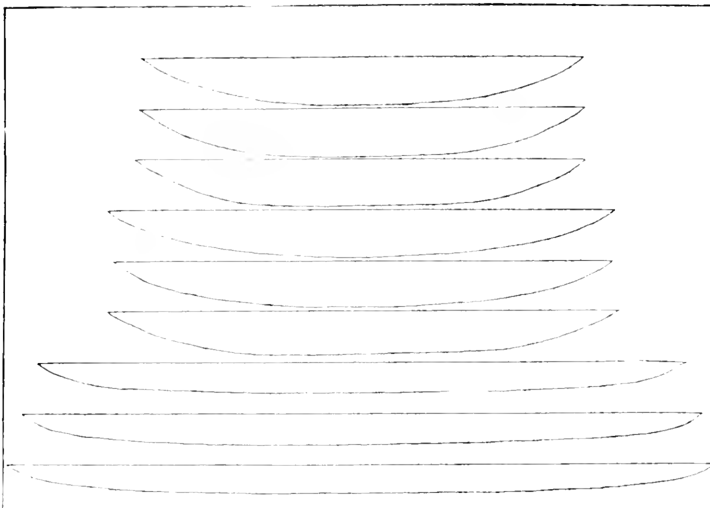
The writer has made some experiments in one branch of this subject, that is, for a straight reach. This involves the simplest form of the equation $Q\,H = f$ (cross-section), since the cross-section is in this case symmetrical as regards the centre line. The more complicated form for unsymmetrical sections, or rather, the general problem of bend development, should come after the straight reach had been solved.

Before taking up the experiments, as a general summary, the condi

tions are, there shall be uniform flow in a homogeneous material in a straight reach and the cross-sections shall be in equilibrium with the forces; the conclusion is, there is one cross-section and only one for each value of discharge and slope.

Some of the cross-sections of these experiments with their respective values of discharge and slope are presented on Plate B. The mean velocity for each cross-section has been also given, furnishing some illustration of how velocities are constrained by the material, as before stated. The variation of velocity shown is hardly more than the possible error of measurement while slope changes through a ratio of about 1 to 3. In the sections presented there is apparently a variation in velocity, giving a

PLATE B. Scale: 1.48 feet = 6 inches.



Q	H	V_n
0.0241	0.0037	0.87
0.0241	0.0041	0.84
0.0241	0.0052	0.83
0.0250	0.0048	0.82
[illegible]	0.0054	0.80
0.0250	0.0063	0.83
0.0251	0.0050	0.89
0.0251	0.0086	0.88
[illegible]	0.0097	0.91

minimum for the middle slopes. This is believed to be an accident of the errors of measurement, as other sections about as carefully taken do not show it.

The units for the values given are for slope, fall in feet for one foot of length, for mean velocity the foot per second, and, for discharge, the cubic foot per second.

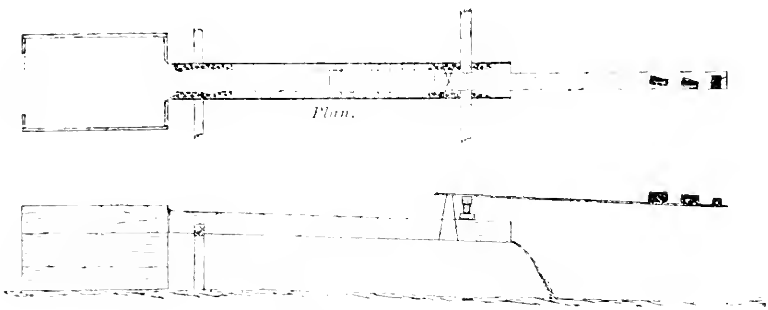
In these experiments which the writer was enabled to make through the kindness of Colonel Flad, there were two questions to settle at the beginning. First. What might be considered a constant material? In regarding material as one of the independent variables in river phenomena, the strictly mathematical term of "constant" is preferred to the rather indefinite one of "homogeneous." Second. How closely would the cross-sections in equilibrium be developed by the action of the forces?

First, as regards material, the range in experiment was too small to get beyond conjecture, except for the material in which sections shown

on "Plate B" were taken. This material was river sand, and the writer is satisfied that there is little error in calling it constant. In regard to the second question, it was, of course, apparent that in water without sediment you could not work in the direction of change from greater to less slope, discharge being constant; for if the cross-section had taken that form where it could furnish without movement of material a resistance equal to the greater energy, it would not move for the less. The experiments were therefore confined to change from less to greater slope, and it was concluded that a cross-section, at least, close to the section of equilibrium, would be developed in this direction.

These conclusions were reached as follows: Arrangements were made for securing at will a constant discharge in a trough that could be easily set at any inclination. This trough was then filled with the material that was to form the bed of the stream, a straight channel made in it,

PLATE C. Scale: 7.7 feet = 1 inch.



Elevation.

and the discharge turned on. The inclination of the trough was then increased until the energy was moving the material at every point of the bed; it was then left until the movement stopped and the cross-section was noted. A greater inclination was then given, and so on until a considerable range of slope had been covered. The whole series would be then repeated a number of times. Now, when the same cross-section was developed each time for a given inclination of trough, the two-fold conclusion was reached, that the material might be considered a constant and that the cross-section depended alone upon slope (discharge being constant) and was therefore the theoretic cross-section of equilibrium.

I should state that the cross-sections developed for the same inclination of trough were not exactly identical each time, but it was also found impossible to make the slope of the water surface identical, and the difference between cross-sections was so slight that it was thought that it was fairly accounted for by this difference in slope, not to mention the possibility of slight divergence from uniform flow existing. It would be too long to give all the details of these preliminary experiments, but altogether, watching them with no wish to cut out for myself work for nothing, I was led to the conclusions stated above.

Being satisfied, then, that the given material might be regarded a

constant as affecting the development of cross-section, and that the cross-sections developed under the artificial control of the forces were close to the sections of equilibrium, I measured carefully the discharge slope and cross-section through as large a range as I could with the apparatus that I had. The apparatus is shown on "Plate C." It will be seen that the upper and lower ends of the trough were filled with gravel to resist the tendency to wash out there. The ranges, where sections and slopes were mostly taken, are also shown.

The range of the experiments was practically only a series of cross-sections for a variation in slope, since but a small change in discharge could be made with the apparatus. The range in slope, however, about covered the variation possible between the physical limits for that discharge; the lower limit being that slope that would just move the material in the least resisting cross-section, the upper limit being such excessive slope that it was hardly possible to maintain a straight reach, movement of material becoming localized and going on to the development of bends before the equilibrium of the straight reach had been attained.

Enough points in this range to indicate the general character of change are given on "Plate B."

A word here in the nature of repetition. These cross-sections were in a straight reach in a constant material where a condition close to uniform flow existed, and, hence, where energy or $Q\,H =$ resistance, they were formed by an excessive energy which first caused a general movement of the material, which movement slowly stopped under the changes that were taking place in energy and cross-section; they could be reproduced any number of times by reproducing the discharge and slope; they were therefore the results of the operation of a law of formation of cross-section dependent on discharge and slope, which law, when determined, expresses the relation that must exist between discharge, slope and cross-section for these experiments on the one hand, and a stream of 100,000 cubic feet per second on the other, subject to the conditions of constant discharge, straight reach and uniform material.

A word more in regard to the sections. Their extreme symmetry is due in part to a mechanical adjustment that was thought legitimate; from small to moderate slopes, this adjustment effected no appreciable change. In excessive slopes, the adjustment was thought to eliminate incipient bend development. The adjustment was as follows: From the centre line the two half sections were folded together, and the mean line taken to represent the symmetrical section.

I have made no attempt as yet to express this variation in an empiric equation, and shall not until I can extend the data. The first step in deducing such an equation would be the choice of a function of cross-section to use, and it could only be a wild guess to choose this function from a variation in slope alone, which is practically all I have. I hope in time to extend it through a considerable range of discharge, which will give the data for a general solution; after that, the investigation for different material will complete the problem for a straight reach.

These sections have been spoken of as sections of equilibrium; to avoid any misconception, it is stated that this does not mean stable equilibrium, but only the equilibrium for a straight reach, and it is well

known that a straight reach is very far from a stable equilibrium, where slope is great and the material of bed is light. As suggested before, those sections for greatest slope on "Plate B" were found, in experimenting, in much the same equilibrium as an egg set on its small end.

Briefly considering some of the practical results of the solution of this problem and the one that follows it, for unsymmetrical sections, or the law of bend development: it has been seen on "Plate A" that the river cross-section was constantly changing; it is thought that this change is around some mean condition and that this mean condition is in equilibrium with the ruling energy at that point; if the above is the case, a step will have been taken toward the exact determination of the theoretic limits of improvement, and it may in time open the way to a comparison of cost for the attainment of given results by regularization or reservoirs.

The need, at present, however, is some general formula that is applicable to rivers for use in the study of data collected, and no formula that does not traverse the change of resistance due to a change in shape of cross-section is applicable. It needs but the statement that those reaches of the river which have the greater slope are frequently the reaches which have the smaller mean velocity, to show that formula that are derived from series of experiments in which the cross-section is unchangeable, and velocity increases with slope, are, in this case, simply worthless. The fact is, the principal variable is cross-section, in rivers, while most hydraulic formulæ have massed its effect in an empirically chosen constant, and, for rivers, if this constant is found for one time or place, it differs for the next, as any one may see by an hour's experimenting with river data. The writer has come to the conclusion that the only formula that is known to be true for rivers, is $Q = A\ V_m$, and, that the only reason that is true, is because V_m is defined as $\frac{Q}{A}$.

The chief interest to the writer, however, lies in the method proposed for the study of river problems, and, however much the conclusions advanced in this paper may be modified by further experiment, there is the conviction that steady progress can be made on this line. It is recognized that river phenomena are too complex for any one to take in, except in fragments; or, if he does get a comprehensive view, he has so much to see that he cannot think. Some of the essential conditions though are being understood, and the writer earnestly wishes to call attention to the fact that if the phenomena due to these conditions are experimentally determined as the conditions are perceived, it will leave a constantly narrowing residual of phenomena not referred to law, which must in time vanish, and then river work will stand on the ground of an exact science.

Before closing, I wish to acknowledge my indebtedness to Mr. L. E. Cooley for the early direction of my thought toward this line. While not wishing to shoulder on him a support of conclusions to which he may not exactly agree, I do wish to recognize that I owe to him the foundation from which I am working, as well as the clearness with which I first saw that the study of *cause*, in this case, is the true end of the study of phenomena.

In conclusion, let me say that I am sorry to have so heavily seasoned my facts with theories, but, as in river hydraulics, even among those who have specially studied the subject, the safe assumption is that no two men agree on anything, the only way to present conclusions that are believed to be of value is to carefully state the steps leading to those conclusions: and the above paper is open to grave criticism by me on account of the omission of some things that I had considered, and that I ought to have introduced, and which I did not, because I did not feel justified in giving any more theory with nine cross-sections.

THE FEASIBILITY OF AN INVERTED SIPHON TUNNEL FOR IMPROVING THE WATER-POWER OF THE ILLINOIS RIVER AT MARSEILLES, ILL.

By Ebin J. Ward, Member of the Western Society of Engineers.

[Read November 17, 1885.]

The utilization of the grand rapids of the Illinois River at Marseilles, La Salle County, long engaged the attention of capitalists and engineers before any active steps were taken to overcome the difficulties that impeded progress.

That a very large water-power lay on the Illinois River within seventy-five miles of Chicago was known to many, but in those days the mountain streams of New England supplied with manufactured goods not only this country, but parts of Europe. Gradually the internal commerce of our own country developed until at last the water-powers of the Western rivers were called into use.

In 1865 a company was formed, which the following year completed the construction of a seven-foot dam across the Illinois River at Marseilles. This dam, according to the estimates of competent hydraulic engineers, was capable of furnishing, in extreme low water, a total of 3,000 horse-power. It was made of hewn timbers roughly framed into cribs, which were filled with stone. A race was dug through a slough at the north end of the dam, and a small mill or two erected. With this beginning was laid the foundation of what has since developed a property worth a million dollars.

The successors of the water-power company, which built that dam, now own the use of three-fourths of the water which passes down the Illinois at this point: the use of the remaining one-fourth is vested in a private individual who is desirous of utilizing it. It is obligatory that the use of this one-fourth of the water should be made on the left, or south side of the stream. Within eighteen months the present water-power company has removed the old dam and constructed a new one, 9 feet high, on an improved plan and out of 12 inch by 12 inch oak. The dam from abutment to abutment is 930 feet long, and, while at low water it gives more power than the old 7-foot dam, at an average height of water in the river there is a total of not less than 10,000 to 12,000 horse-power.

The Illinois at Marseilles flows through the centre of a valley one and a half miles wide. Like most of the streams of a prairie country, it has


Scale 4 chains = 1 inch
MAIN ST.
RANGE
DEPOT GROUNDS
WARD.
Note: The location of proposed Tunnel has been put on this plat which was originally made for other purpose.

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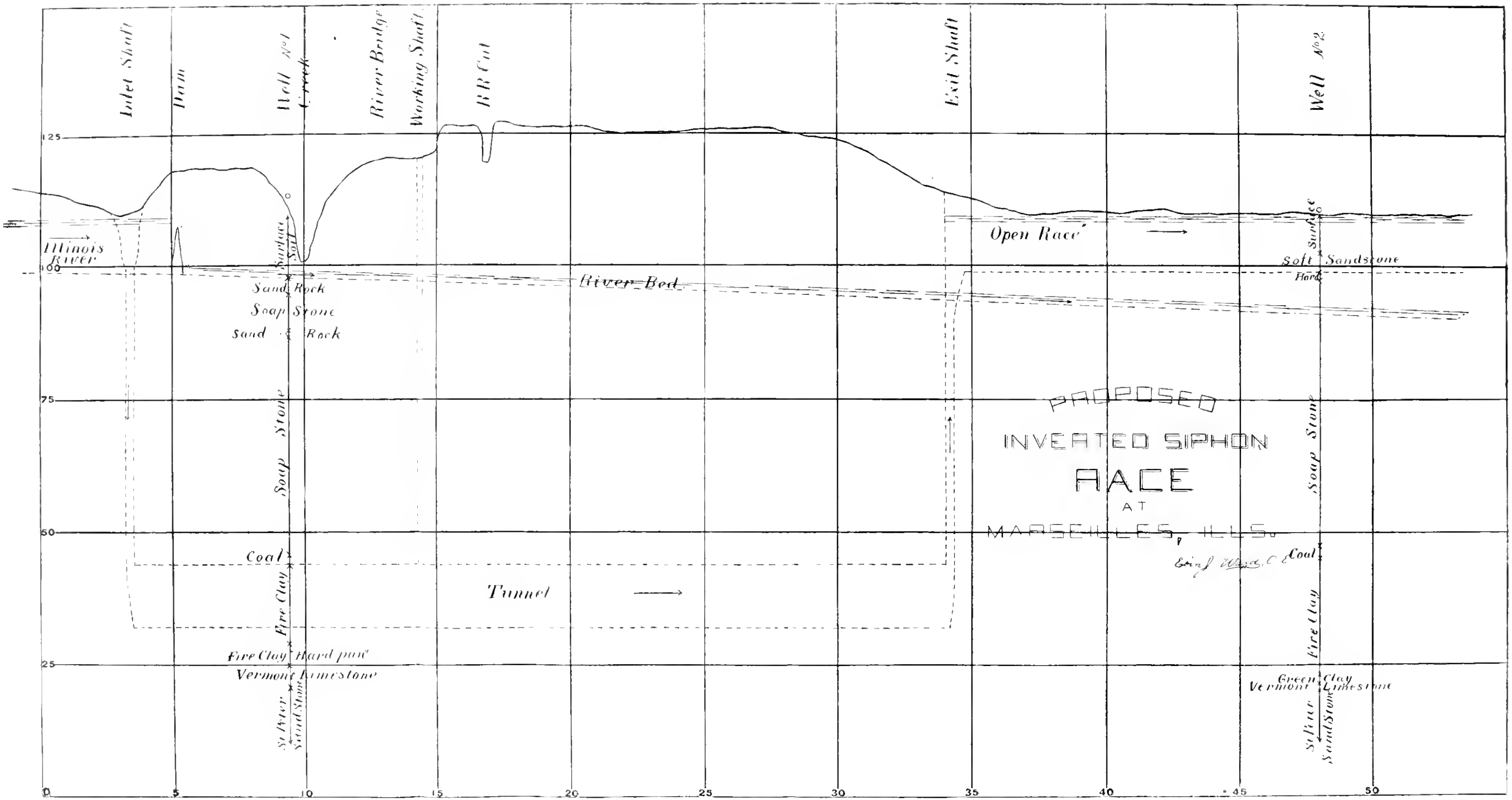


Inlet Shaft
Dam
Well No 1
Creek
River Bridge
Working Shaft
R R Cut
Exit Shaft
Well No 2
Illinois River
Open Race
Surface Soil
Soft Sandstone
Hard
River Bed
Sand Rock
Soap Stone
Sand & Rock
Soap Stone
PROPOSED
INVERTED SIPHON
RACE
AT
MARSEILLES, ILLS.
Coal
Fire Clay
Tunnel
Fire Clay Hard pan
Vermont Limestone
St Peter Sand Stone
Green Clay
125
100
75
50
25
0
5
10
15
20
25
30
35
40
45
50

one bank, in this case the right or north one, that is low and alluvial, while the other is high and precipitous. This topography proved convenient to the water-power company in the construction of its headrace, but it has more than once given rise to alarm from the danger of overflow, and has caused them to construct a dyke nearly half a mile long.

The south side of the river back to the bluff, a distance of over three-quarters of a mile, is level and universally higher than the north side, save at one place close to the river. At the dam and for about 3,000 feet below, the south bank is precipitous and is, on an average, 23 feet higher than the bed of the stream; but at the above distance below the dam this bluff recedes from the river for about 600 or 700 feet, and leaves a low plain of about 20 acres. This plain is on a level with the opposite bank of the stream and, consequently, it presents no more difficulties to the construction of open cut races than the opposite bank. But to dig an open raceway through the high bluff from the south abutment of the dam to the above-mentioned low plain would, according to my estimates, require the removal of 44,000 yards of earth and 3,900 yards of shaley stone, and the construction of, at least, two bridges to carry the highways across which the race would have to be cut. The total cost of carrying out this plan would be in the neighborhood of $17,000. Besides this, so deep an open cut would, of necessity, destroy considerable valuable surface.

It was suggested by a prominent member of this society that an estimate be made of the cost of the following plan: To run an open cut in a semi-circle from the river just above the dam into the small ravine—shown on the plat—which opens into the river just below the dam, and from there carry the water under the steep bank of the river for 1,200 feet by means of a stone wall, until the low plain above mentioned is reached, and then carry the race back from the river by means of an open cut. Owing to the trend of the stream the water and ice strike the south bank exactly where this wall would have to be built, and, consequently, the wall would have to be well and strongly constructed. In the estimate of the cost of this plan must be considered 1,600 cubic yards of masonry, which raises the total to nearly the same figure as that by the previous plan, viz.: $16,000.

A third plan presented itself to my mind. A bed of most excellent and valuable fire-clay underlies the line of the race-way at a depth of 54 feet below the bed of the river. This vein of clay is from 17 to 22 feet thick. Immediately over it lies 27 inches of bituminous coal, and next above the coal comes 49 feet of hard soapstone, and then 3 feet of sand-rock, which forms the bed of the river. Above this sand-rock is surface soil and a poor quality of fire-clay mixed. The above data was obtained by drilling two well-holes to the depth of 100 feet below the surface. The third plan consists of sinking a vertical shaft close to the water's edge down to this fire-clay and 100 feet or 150 feet above the south abutment of the dam. Thence digging a straight, horizontal tunnel through the fire-clay, using the coal for a roof, from this inlet shaft for about 3,000 feet, to meet a vertical exit shaft sunk in the before-mentioned low plain, from whence an open cut can be made at very little expense. By

this means water entering the inlet shaft will sink to the tunnel, and, rising in the exit shaft, will be ready for use in the low land down stream. It should be borne in mind that the fire-clay through which the tunnel would pass is quite hard and would have to be blasted out.

With a tunnel having a cross-section of 12 feet by 12 feet, no timbering would be needed, for no "squeeze" is obtainable even in the coal mines in this neighborhood until after a heading of from 125 feet to 145 feet in width is obtained, and so soon as the tunnel is completed and filled with water the hydraulic pressure will, certainly, keep roof and walls from caving. The 49 feet of soapstone overlying the vein of coal would make an excellent roof in itself, and so permit of the removing of the coal in the tunnel, also, were it not for the fact that, when exposed to the action of the air, the soapstone gradually slacks. It is far more for the purpose of keeping the air from the soapstone above, during construction, that it will be advantageous to retain the coal in the tunnel, than for any great supporting power that might be in the vein of coal. No water is found in or above the fire-clay.

The quantity of water that is permitted to pass through the tunnel can be regulated by suitable gates, either at the inlet or the exit shaft, or at both. The inlet shaft, being close to the edge of the water above the dam, fenders and gratings can be placed close to it in the stream to prevent any ice or drift from entering the tunnel. Here it may be remarked that the Illinois River is practically free from driftwood, even at its floods. Mills, located on the open race-way below, will not be troubled during the winter by broken ice clogging the screens before the wheels, for the water on rising from the exit shaft will, almost immediately, enter the wheels.

I have neglected to say that an excellent new wrought-iron bridge is now in process of erection across the river, about 1,200 feet below the dam. In order to facilitate the removal of the fire-clay, as well as for the purpose of saving "haul," a working shaft may be sunk close to the south end of the bridge and work be pushed from it toward both the inlet and the exit shafts at the same time. From a working shaft so located carts can readily transfer the fire-clay to either the side-tracks, of the C., R. I. & P. R. R., which are less than half a mile distant, or to the Illinois & Michigan Canal, still nearer.

The expense per ton of placing the clay on top of the ground will be surprisingly small, for a heading can be made by removing the clay with picks for a foot or two below the coal, and then a few charges of dynamite will blow up the bench, thus formed, and loosen tons of clay.

The clay has been thoroughly tested by two large consumers in Chicago, and each has expressed a desire to use it. From such a tunnel, made 12 feet by 12 feet, there would be excavated clay enough for about 5,000,000 fire-brick. Brick made from this clay have been severely tested on the bridge-walls of the gas furnaces at the Joliet Rolling Mills by the side of both No. 1 and No. 2 fire-brick—the latter coming from Ohio and West Virginia—and the report of the engineer who made the tests contains the following statement: The brick from Marseilles clay is "as good as any No. 2 brick the mill has ever used."

As to the action in the tunnel of running water upon the clay, I would say that tests have been made with the most excellent results, by wholly

submerging pieces of the clay in the river below the dam, where, on the rapids, the water flows with a much higher velocity than it will be required to in the tunnel. The following are the results obtained from those tests: On Sept. 26, 1883, an irregular piece of fir-clay, weighing 24½ pounds, was placed in the rapids below the dam; on Oct. 15, 1883, it weighed 24½ pounds; on June 9, 1884, after having been exposed to the action of the water for nearly nine months it was taken from the water to be weighed, but in doing so it was, accidentally, permitted to drop to the ground, and several pieces were chipped off. All the pieces which could be were collected and weighed with the large piece, but many small pieces remained among the gravel and earth. The piece as weighed was 24¼ pounds. On Sept. 22, 1884, another piece of the clay was placed in the rapids weighing 19½ pounds, and on June 15, 1885, after being in the water nearly ten months, it still weighed 19½ pounds, showing no erosion, although exposed during the whole period to the action of a severe current. After remaining in the water for a few days the clay becomes coated with a smooth, green slime and all the edges and corners remain sharp and clearly cut, showing that running water does not even round them off. The clay, when submerged, is, evidently, capable of wholly resisting the action of running water. The smooth, straight walls of the tunnel will not be so exposed to erosion as were the irregularly broken pieces of clay used in these tests. The clay can, certainly, all be sold, at the very least, for what it costs to remove it, so that as the tunnel progresses each lineal yard dug will pay for itself.

The cost of a race-way constructed in this way will be far less than by either of the foregoing plans. My estimate is that it will not cost to exceed $5,500 to construct both working-shaft, entrance and exit shafts, tunnel, open raceway below in the low ground, and furnish all with the necessary gates and valves for controlling the flow of water.

After careful examination, experimenting and thought, I can see no reason why this plan is not perfectly feasible, and, if carried out, will not make a permanent improvement. But suppose that, after the tunnel is partially completed, some insurmountable obstruction should be met with that would prevent the completion of the tunnel. In that case about all that would be lost is the labor in the construction of the working shaft, for the hoisting machinery can be sold for what it is worth; each lineal foot of tunnel will have paid for itself as it is being dug through the clay, and the inlet and exit shafts need not be sunk until the tunnel has attained its full length, and its feasibility has been thoroughly demonstrated.

THE DEVELOPMENT OF TRANSPORTATION IN NORTHERN OHIO.

By John H. Sargeant, Member of the Civil Engineers' Club of Cleveland.

[Read September 8, 1885.]

Those of us who remember the old "Pennsylvania schooner," a large rakish, covered wagon, with four, six, or more horses attached, with its driver with his "black snake" whip astride of his nigh wheel horse, and the old "Concord coach," can fully realize the rapid march of events.

Nature provided water-ways, but man, by his own devices, must work his way to them.

The transition from the canoe of the savage to the floating palaces of civilization, from the muscle of man, as a moving force, to the winds of heaven, was natural and gradual. Even the making of artificial rivers—water-ways—was but mimicking Nature.

The Indian could even harness his pony to his pung to drag his tents and scanty wares over the trails he had sought out over the country. But it was a new departure to construct great highways and cover them with wheeled carriages, and harness the power of coal and water to them.

The transition from the canoe to the steamer and the flying train is wonderful, but what an insignificant part of time in the world's history is occupied.

A single life upon the borders of these great lakes comprises it all.

Transportation in northern Ohio naturally reaches out to Buffalo on the East and Chicago on the West as a grand division in the transportation of our country, and I shall so treat of it.

The early roads of this section were celebrated for their badness, some of them in spring and fall becoming almost impassable.

The most important roads were turnpike roads, toll roads, and were built through the woods of the rich mucky soil of the country.

One of the first out of Cleveland, the "Cleveland, Wooster and Mt. Vernon Turnpike," was built about 1820, and those who eighteen years later went over it, in a brig drawn on wheels, in the celebrated Harrison campaign, can certify to its continual badness.

A little earlier than 1840, macadamized roads began to be in vogue. The National road was carried through the central part of our State, and the dreaded Black Swamp, from Lower Sandusky (Fremont) to Perrysburg, was spanned by a beautiful stone road.

Population and production were fast outgrowing our ways. Our State was surrounded by water-ways and the Concord coach and Pennsylvania wagon soon became unequal to work the business from the centre to the circumference.

The State of New York had opened out Lake Erie to the Hudson, and in 1847 Ohio bisected the State by the Ohio Canal. By the improvement of Huron River lake craft were enabled to meet the loaded wagons from the centre of the state, at Milan. The Maumee Canal followed and

sent boats from Lake Erie to the Ohio at Cincinnati, and through Indiana to the navigable waters of the Wabash.

Here canals reached their climax. They were too slow and could not go where they would do the most good.

The contest for the location of the Ohio Canal had been fierce and close, and Sandusky felt that they had been left out in the cold. The locomotive began to whistle in the East. Sandusky grasped at the new means of transportation.

Exact dates are not at hand, neither is it material. Suffice it to say that about 1838 the Ohio Legislature passed what is known as the "Plunder Law," to aid in the construction of railways, by which, when the railway companies had expended a certain sum on their roads, the State would loan them a like amount of State bonds. Under this law Sandusky opened the Mad River & Lake Erie Railroad as far as Tiffin.

The New York & Lake Erie Co. were pushing their broad gauge road towards Lake Erie. To meet it a company was formed to build the "Ohio Railroad" from the Maumee River to the east line of the State. They began at Manhattan and started a bank at Cleveland. By hook and by crook, by putting in lands, etc., they made a showing that they had laid out $250,000, and got a like amount of bonds, and doubtless absorbed them. The people got the idea that they were being plundered and repealed the law, whereupon the company failed, and left in the hands of the people a large amount of Ohio railroad bills instead of a railroad. In the meantime Sandusky had built a flat bar railroad to Monroeville, sixteen miles, and Toledo had sent out the Erie & Kalamazoo road, thirty miles, to Adrian. Here railway construction took a short rest. But as early as 1845 Burr Higgins, a banker of Sandusky, took hold of the Sandusky, Mansfield & Newark Railway, now the northern branch of the Baltimore & Ohio. He took up the old flat bar, substituted T rail and pushed the road through to Mansfield. There was a provision in his charter requiring him to let other roads run over his. The banker thought he was smart enough for any legislator, so he made his road of a five foot six inches gauge, so as to be different from any other road in existence. His road was never good for much until he changed its gauge to the standard.

The Mad River & Lake Erie Railway was gradually pushed through to Cincinnati.

About this time the State of Michigan went into railroad building and built some sixty miles of the Michigan Southern road from Monroe to Hillsdale, and something more of the Michigan Central from Detroit west. Both these roads were laid with the flat bar.

Cleveland and Columbus began to see that they were going to be left in the background, and in 1848 commenced the agitation of the C., C. & C. Railway, and completed it in 1850–51.

About this time the eyes of Wall street began to be opened to the importance of the granaries West. Steamers and sailing vessels had multiplied upon the lakes. Chicago and Milwaukee began to show signs of their future greatness. The politicians of Michigan were tiring of public works, railway construction in particular, so the New York lobbyists found it easy to buy their roads, and with them favorable charters.

The Michigan Central R. R. Co. secured the Central road, and the Michigan Southern & Northern Indiana R. R. Co. secured the Michigan Southern route. Simultaneously, or nearly so with the broad gauge movement from New York to Toledo, a charter was secured for the Buffalo & Mississippi R. R., extending from Toledo to Chicago, but nothing came of it except some hasty surveys and a little grading between Laporte and Michigan City, Ind. This charter was worked into the Michigan Southern & Northern Indiana Co. Surveying operations on this were commenced in 1849, and work in earnest in 1850. The Michigan Central Co. pushed their work forward simultaneously. Singular as it now seems, the competition between these two works became very fierce, and they threw all possible obstacles in each other's way. This was because they thought that there was only business enough for one road.

The M. S. & N. I. Co. absorbed the old Erie & Kalamazoo road and rebuilt both with T-rails, and sent out several branches, one of which, the "Air Line," extended from Toledo to Elkhart, half way to Chicago.*

To connect their road with Buffalo, the M. S. & N. I. put in commission the fast palace steamers, the Michigan Southern, the Northern Indiana, the Western Metropolis and the City of Buffalo, and the Central Co. the Plymouth Rock. This was the culmination of the passenger steamboat business upon the lakes. It was soon driven from the route by railroad competition, brought about by the construction and consolidation of the Cleveland & Toledo, the Cleveland, Painesville & Ashtabula, and other roads between Buffalo and Toledo, and the absorption of the "Junction road."

Then followed the Cleveland & Pittsburgh and Cleveland & Mahoning; the Pittsburgh, Fort Wayne & Chicago, and the Atlantic & Great Western Railways, with their branches, and what is now the Cleveland, Akron & Columbus Road.

Later came the coal roads—the Tuscarawas Valley, the Valley and the Connotton Valley roads. The railroad business grew up so rapidly, and those in operation became so successful, as to excite the cupidity of capital, and several competing lines were constructed. Besides those that escaped Ohio on the North, the New York, Chicago (Nickel Plate) & St. Louis paralleled for 250 miles the Lake Shore road, and thence through to Chicago via Fort Wayne, and the old New York & Erie, and the Baltimore & Ohio, pushed through Northern Ohio to the emporium of the West.

* The Wabash and Erie Canal had already given New Yorkers a taste of the Southwest also, and their Air Line branch bore off to the south and west for 70 miles from Toledo, where, in company with Eel River Railroad Company, they purchased 160 acres of land. In the meantime, the Assistant Chief Engineer of the M. S. & N. I. R. R. was made Chief Engineer of the Eel River, and this road was located and in the main graded with the expectation that the M. S. & N. I. would furnish the iron. But by some sort of sharp practice the Wabash Valley Railroad Company was able to pay bigger commissions on iron than the Eel River road; so the Eel River was abandoned and the Wabash Valley, its strongest rival, was pushed through. Now the Wabash is in trouble, and it is whispered about that the L. S. & M. S. is about to acquire the Eel River, and it is a very important feeder for them, as this route is shorter and better to Logansport than by the Wabash Valley.

As might be supposed, all this fierce competition has reduced freights so low as to give little income to the capital invested.

Amid all this activity on shore, the lake men have not been idle; the passenger business they surrendered, but by the use of great steam barges with their consorts they are able to carry freight for a mill per ton per mile, a rate which, when time is not a controlling element, shuts out land carriage during the season of navigation.

In all this effort to meet the growth of business transportation may have gotten a little ahead of its requirements. But the country is as yet but partially developed, and the effect of all these lines of transportation is to swell business, so all they have to do is to rest for a time on their oars and ere long they will be flooded with business.

If we take the case of the New York Central R. R., and consider how rapidly its facilities have grown from a single track of iron to six (including the West Shore) of steel, we can form some idea of the field that is open before us. The tendency now seems to be towards the consolidation of lines. It is to be hoped that this system will not be carried so far as to excite the jealousy and resistance of the community. The most effectual means of preventing the construction of more lines of communication than required to do the business is for capital to be content with reasonably low interest for the moneys actually expended. According to the present outlook, an assured interest of more than four per cent. will call in idle capital to share it to build new lines.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ASSOCIATION OF ENGINEERING SOCIETIES.

ANNUAL REPORT OF THE CHAIRMAN.

To the Association of Engineering Societies:

The year ending with November, 1885, was a prosperous one for this Association. Early in the year the Civil Engineers' Society of St. Paul became a member of the Association, and Mr. C. J. A. Morris was chosen their representative in the Board of Managers. In other respects the Board is constituted as one year ago.

No meeting of the Board has been held, and no new measure instituted during the year, except the publication of an Index of Periodical Engineering Literature, which was begun with Volume IV., in accordance with a decision of the Board, previously announced. The Index has been published month by month since it was begun. The last issue for the volume contains a general summary alphabetically arranged of all the matter previously published. The Index, as finally compiled, covers 46 pages of condensed, closely printed matter, which in the course of a few years will become invaluable for reference on all engineering subjects contained in official reports, professional journals, and society proceedings. The monthly publication of the Index, and its re-publication in the end of the year, has added considerably to the cost of the JOURNAL. It has, however, fully compensated for this extra cost in the increased income from sales and subscriptions. This fact, together with the palpable advantages otherwise derived from the Index, are ample justification for its continuation, and the Board feels warranted in announcing that this feature is to be maintained, and its efficiency increased from time to time, as the remuneration growing out of it justifies the expense thereby incurred.

As previously stated, the Association is indebted for this work to Prof. J. B. Johnson, of the Engineers' Club of St. Louis.

Aside from the additional expense incurred on account of the Index, the financial statement shows an increase of receipts and expenditures due to the steady growth of the Association, and to the larger edition printed now than formerly. But notwithstanding this increase, the pro rata cost of the JOURNAL was somewhat less than for any previous year.

The average number of pages of reading matter in each of the first three volumes of the JOURNAL is 367. The number for Volume IV., exclusive of the Index, was 424.

The success thus far attending the efforts of this Association to concentrate the records of engineering work seems to have begotten a spirit of co-operation along other lines of professional interest, and the Association is to be congratulated that such is the case. But whether this tendency is the unconscious fruit of our efforts to bring about a better condition of affairs in the societies and with the profession at large, or whether it is of parallel growth, springing from the same motives that created the Association, we need not stop to inquire. It is enough that a habit of co-operation is being acquired by many of the scattered societies of the country, and that a desire for the same is being manifested in quarters which hitherto have shown no such tendencies.

The recent organization of the Civil Engineers' Committee on National Public Works, which bids fair to secure the co-operation of all our engineering societies in promoting objects of first importance to the whole country, as well as to the

engineering profession, is one of the signs of the times. Another one which we are pleased to notice is that the pioneer society—the American Society of Civil Engineers—is awakening to the desirability of an organization which will be more representative and national. Whatever the immediate results of this awakening, its ultimate effects will necessarily be to promote the primary purposes of this Association, viz.: the ultimate formation, on a national basis, of an association of engineers in localized sections, which will not only secure the broadest co-operation in the publication and diffusion of engineering literature, but which will make its influence felt in the promotion of all measures calculated to improve the profession and better its public status. It is impossible that this habit of co-operation should not become general, and that it should not extend into new fields and grow to large proportions.

Statistical and Financial Statement.

The number of copies of the JOURNAL taken by the several societies has increased from 524 to 572. They now stand as follows:

Boston Society of Civil Engineers	147
Western Society of Engineers	106
Engineers' Club of St. Louis	127
Civil Engineers' Club of Cleveland	132
Engineers' Society of Minnesota	39
Civil Engineers' Society of St. Paul	21
	572

During the year assessments to the amount of $3 per copy were collected in three installments.

The expenditures of the Association for Vol. IV. are as follows:

Composition, press-work, paper, binding and mailing	$1,588.27	
Engraving	195.01	
Expenses	402.74	
Postage	100.80	
Deficit Vol. III	30.46	
		$2,317.28

Receipts:

Boston Society of Civil Engineers	$375.00		
Western Society of Engineers	351.00		
Engineers' Club of St. Louis	358.00		
Civil Engineers' Club of Cleveland	410.00		
Engineers' Society of Minnesota	93.00		
Civil Engineers' Society of St. Paul	49.00		
		$1,636.00	
Sales	$125.08		
Subscriptions	201.74		
		326.82	
Advertising		322.01	
			$2,281.83
Leaving a deficit of			$32.45

The deficit for Vol. IV. being within a few dollars of that for Vol. III., and the assessments during the year being $3.00, shows that the cost of the Journal has been reduced slightly, viz., from $3.16 per volume per copy for previous years, to $3.00 for the past year.

It will be noticed that the receipts from sales and subscriptions have increased from $75.25 for Vol. III. to $326.82 for Vol. IV. The greatest income from this source for any previous year having been $116.78, this increase is believed to be largely due to the Index, and fully justifies, from a financial stand-point, the additional expense incurred by its publication.

The assets of the Association are approximately as follows :

100 copies of Vol. II. @ $2.50	$250.00	
100 " " III. @ $2.50	250.00	
175 " " IV. @ $3.00	525.00	
1200 " of No. 12, Vol. IV. @ 25c	300.00	
Advertisements due	105.74	
		$1,430.74
Less deficit		32.45
Total assets		$1,398.29

Respectfully submitted on behalf of the Board of Managers.

CHICAGO, Feb. 11, 1886. BENEZETTE WILLIAMS,
Chairman.

BOSTON SOCIETY OF CIVIL ENGINEERS.

DECEMBER 16, 1885 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:40 P. M.

President G. L. Vose in the chair, forty-one Members and three visitors present.

The record of the last meeting was read and approved.

A communication from the New England Railway Club was read containing the following proposition : "That the New England Railway Club and the Boston Society of Civil Engineers hold a joint discussion on the Relation of the Road Bed to the Rolling Stock and the Methods, Forms and Material Best Adapted for Use in Their Construction."

The report of the Government was read recommending that the invitation of the New England Railway Club be accepted and a committee of conference be appointed to complete arrangements.

On motion of Mr. Henry Manley it was voted that the President be requested to appoint a committee of three as recommended by the Government. The committee as appointed consist of Messrs. G. R. Hardy, H. Bissell, L. B. Bidwell.

The proceedings of the Convention held at Cleveland December 3, 4, 5, to consider the relation of Army and Civil Engineers in the Government service, were read by the Secretary.

The Committee appointed to arrange for the transfer of the Society's library and report plans and estimate of the cost of furnishing the rooms submitted its report, and presented the Society, in behalf of Mr. Desmond Fitz Gerald, a table for use at its meetings. The report of the Committee was accepted.

On motion of Mr. A. H. French it was voted that this Committee be authorized to purchase the articles named in its report, and that the sum of eighty-two dollars be appropriated from the Permanent Fund for that purpose.

On motion it was voted that the Society is pleased to accept the table presented by Mr. Desmond Fitz Gerald, and that the thanks of the Society be extended to him for his valuable and appropriate gift.

On motion of Mr. A. F. Noyes it was voted that the sum of thirty dollars be appropriated for renewing the Society's subscription to the usual periodicals for the year 1886.

That the sum of thirty dollars or so much thereof as is necessary be appropriated for binding the periodicals of the Society for the year 1885, and for other purposes in the Library.

On motion of Mr. Clemens Herschel it was voted that a permanent Committee on National Public Works be appointed, and that the Chairman of this Committee be the Society's representative on the Civil Engineers, Committee on National Public Works. Yeas, 24. Nays, 5.

On motion of Mr. Fred Brooks it was voted that Messrs. Clemens Herschel, L. Frederick Rice, Thomas Doane be constituted a permanent Committee on National Public Works.

On motion of Mr. H. A. Carson it was voted that Mr. Clemens Herschel be requested to report at the next meeting what action he would ask Congress to take in the matter of National Engineering.

Messrs. E. H. Brooks, W. S. Chaplin, S. Haagansen, H. G. Palfrey and C. H. Parker were elected Members of this Society.

Mr. E. L. Corthell was proposed for membership, recommended by L. Fred Rice, J. P. Davis; Mr. H. C. Keith by L. B. Bidwell, G. T. Sampson; Mr. W. H. Stearns by G. R. Hardy, Walter Shepard.

Mr. H. A. Carson described some Methods of Topographical Surveying in a Rough Country.

Mr. W. H. Bradley alluded to a recent trip through New Mexico and California.

Mr. Sydney Smith gave notice in writing of a proposed amendment to Section 2 of the By-Laws as follows: 2. The following order of business shall be observed at all regular meetings, unless set aside by vote of the Members present:

1. The reading of the record of the previous meeting.
2. Balloting for Members.
3. Business and reports of committees until 8 P. M.
4. Literary exercises.
5. Unfinished business.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

JANUARY 6, 1886:—Club met at 8:15 P. M., at Mercantile Library. President McMath in the chair, twenty members and four visitors present.

Minutes of last meeting were read and approved.

The standing committee on National Public Works reported:

ST. LOUIS, January 6, 1886.

To the Engineers' Club of St. Louis:

GENTLEMEN: Your Committee on National Public Works, to which was referred a motion to approve the action of the convention of delegates from engineer societies held at Cleveland, December 3, 4 and 5, 1885, respectfully reports that, after due consideration it was decided not to be expedient at the present time to indorse or disapprove the action at Cleveland. We therefore recommend that no action be taken on the motion.

We have further considered the question of expense attending our work as Committee, but are not able to form an estimate of cost, which will be limited to postage and stationery, until report is made and sanction of the Club obtained.

Respectfully submitted for the Committee,

R. E. McMATH, *Chairman.*

Moved and seconded that the report be accepted. Carried.

The secretary read a letter from the Treasurer addressed to Executive Committee, showing financial condition of the Club.

Mr. Holman proposed as an amendment to the proposed amendment to Sec. 2 of By-Laws, as follows:

The annual dues shall be, for resident members, five dollars, and for non-resident members four dollars. Carried.

The amendment as amended was carried by a two-thirds vote.

The Executive Committee reported through the Secretary the probable cost of employing a stenographer.

Jas. M. Chaplie was proposed for membership by Edw. Flad and T. J. Whitman.

Moved and seconded that the Executive Committee be authorized to employ a stenographer temporarily. Carried.

Mr. J. A. Seddon read a paper on "Some Considerations of the Relation of Bed to Variables in River Hydraulics," which was discussed by Messrs. McMath, Moore, Ockerson, Johnson, Johnston and others.

[*Adjourned.*] THOS. D. MILLER, Secretary.

JANUARY 20, 1886:—Club met at 8:15 P. M., at Mercantile Library. President McMath in the chair and nine members present.

Minutes of last meeting were read and approved.

The Executive Committee reported, recommending Jas. M. Chaplie be elected a Member of the Club. He was balloted for and elected.

The Committee reported the adoption of the following rule: *All papers read before the Club and intended for publication shall be forwarded to the Secretary for consideration by the Executive Committee, as provided in the By-Laws.*

The Committee recommend the adoption of the following amendment to Sec. 8 of the By-Laws (add to the section): "The sending of the JOURNAL to any member in arrears for three months or more, may, by vote of the Executive Committee, be discontinued."

A letter from C. W. Clark, asking that he be classified as Non-Resident Member was read. The Club decided that as he was a resident on the first of January (when the dues are payable) that he was still a Resident Member.

The Club cast a vote of thanks to Mr. Wm. E. Worthen for a handsome copy of "Cyclopedia of Drawing" donated by him.

Mr. P. M. Bruner read a paper on the "Use of Hydraulic Cement," which was discussed generally.

[*Adjourned.*] THOS. D. MILLER, Secretary.

FEBRUARY 3, 1886:—Club met at 8:20 P. M., at Mercantile Library. President McMath in the chair, and twenty Members and five visitors present.

Minutes of the last meeting were read and approved.

Executive Committee reported, recommending that Abraham Cook and Julius Baier be elected Members of the Club. They were balloted for and elected. Also the acceptance of the resignation of J. B. Stone and M. P. Brazill.

The amendment to Section 8 of the By-Laws, proposed at the meeting of January 20, 1886, was adopted.

Mr. M. L. Holman presented some interesting experiments on the commercial brick for engineering purposes.

Prof. C. M. Woodward read a paper on "The Theory of Ammonia Refrigerators." The paper was generally discussed.

Moved and seconded, that Professor Woodward be requested to prepare his paper for publication. Carried.

[*Adjourned.*] THOS. D. MILLER, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. March, 1886. No. 5.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE WORCESTER SEWERAGE TUNNEL.

BY WILLIAM WHITTAKER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read November 18, 1885.]

This tunnel was built by the City of Worcester within its limits, and is located as follows: Beginning on Crystal street, at a point 300 feet east of the Boston & Albany Railroad, thence northeasterly on Crystal street about 1,600 feet, thence northerly on Maywood street about 1,000 feet The total length of tunnel was 2,600 feet. The tunnel section averaged 6 feet by 8 feet 6 inches.

The work was begun in open cut, but after the rock excavation had been carried to a depth of 18 feet, the grade being at this point 33 feet below the surface, it was deemed expedient to resort to tunneling. After shaft No. 1 was started in August, 1884, which required a depth of excavation of 22 feet in rock and 16 feet in earth, so much opposition was made to tunneling that this portion of the work was suspended several weeks. A careful account of the cost of the work in open cut was kept, and as this cost far exceeded the estimate, it was decided to work one section in open cut, and another in tunnel, each section being worked as economically as possible under the circumstances. The result demonstrated that the cost of tunneling would not exceed 50 per cent. of the cost of the work in open cut. Open cut was then abandoned for tunneling, which the author thinks resulted in a saving to the city of Worcester of at least sixty thousand dollars.

The average depth of cutting was about 30 feet; at Main street, shaft 6, it was about 50 feet. The shafts were started about 14 feet square, and were placed about 350 feet apart. Earth was met with in three places. One was 250 feet in length and was tunnelled. The timbering used was as follows:

Starting from the top of the rock as found, small props 4 inches by 6 inches were used, with 4-inch by 6-inch caps, 4 feet long, placed close together. Where the roof was wet 2-inch planks 4 feet long were driven

with a temporary post in the centre to keep the caps from springing until the planks were driven about 2 feet. After going about 6 feet the roof was dry and no more driving planks were used, but the 4-inch by 6-inch caps were continued as before, close together. As the length of the props increased with the dip of the rock they became too long for the lateral strain, and a ranger with braces was carried along on each side. A calculation made to determine the strength of the caps showed that with a factor of safety of five they would carry 30 feet of earth, the maximum load that could come on them, and as a matter of fact we had no trouble with them. In swelling ground calculations seemed to be of no account, for the size of the timbering must be governed by the circumstances of the case. The caps were 3 feet long between props. At the junctions of the timber headings an observer could not tell which side the timbering had been done, the junction being almost perfect. A 1-inch board was nailed under each cap for a cleat.

The other two sections, each about 200 feet in length, were in open cut, in very bad earth mixed with plenty of water. The cost of the open cuts as compared with the tunnel was as 2 to 5, but the author considers this ratio would have been as 1 to 2, if certain conditions in reference to the labor had not been imposed upon him.

A 6-inch drain pipe was laid in the bottom for sub-drainage and kept open for the length of tunnel: the plan being to drive from one shaft to the other before laying any brick. This is the most economical way to lay the brick, providing circumstances will admit it. It very often happens that in bad ground the brick-work must be carried along with the excavation to prevent any serious results from shifting ground.

The drill used in the tunnel was the Little Giant Rock Drill, manufactured by the Rand Drill Co., New York. The air compressor, made by the same firm, was 10 inches by 16 inches, water jacketed, patented in 1872 and 1882. The receiver was 4 feet in diameter and 12 feet long; a second receiver was placed at the end of the air pipe similar to the first one. The air pipes were of the following diameters: 2½ inches from compressor to receiver, 2½ inches to outside of compressor house, then 2 inches for about 800 feet, 1½ inch for about 700 feet, 1¼ inch for about 600 feet, 1 inch for the remainder of the distance. One peculiarity, and it might be to many a paradox, connected with the air pressure was this: with a steam pressure of 60 pounds to the square inch an air pressure of 80 pounds was indicated, the diameters of the air and steam cylinders and the length of stroke being the same in both cases. We had considerable trouble, on very cold damp days, with the air pipe freezing at the valves and elbows; but we had them arranged so that steam could be let on from the different engines along the line, and the whole line was seldom shut off on this account. The greatest trouble we had was with the unions, which were very difficult to keep tight, owing to the expansion and contraction of the pipes after steam heating. This the author thinks might be overcome by having pieces made to telescope one inside the other with stuffing boxes and inserted at different stations, so that the pipes could expand and contract without affecting the joints. The boiler was made by Wm. Allen and Sons, Worcester: length, 13 feet 6 inches; diameter, 4 feet 4 inches; number of tubes, 60: diameter of tubes, 2¾ inches; grate area, 4 feet by

4 feet 2 inches. The total length of brick-work was 19 feet 6 inches; width, 7 feet 6 inches; height, 8 feet 6 inches; distance of bridge-wall below boiler, 5 inches; thickness of the wall, 12 inches, with top course rounded on the ends. The distance from the floor to the top of the boiler was 8 feet. The inside dimensions of the brick-work were as follows: From bridge-wall to back-wall, 8 feet 4 inches by 4 feet 2 inches; thickness of wall, 20 inches, with a 2-inch air space; diameter of smoke-flue, 18 inches; diameter of smoke-stack, 30 inches; length, 45 feet. The compressor did what the author thinks very good work; it kept four drills at work continually twelve hours with one ton of coal. The average amount of coal used per month, with four drills running continually from nine to twelve hours, was twenty-six tons. The machine has been running over a year, and the author considers it almost as good as it was at the beginning of the work. This compressor was also used on a tunnel at Lynn. The drills the author considers did remarkable service. They were worked continually during the time as stated, and the repairs averaged about two dollars per week for each machine. From twenty-two to twenty-four holes, 4 feet deep, were drilled on an average in ten hours, making an average of about 90 feet of drilling in ten hours for each machine. The best record made was 22 feet of heading per week for six weeks; this was going north from shaft 6. The average rate of progress was 72 feet per week with four machines.

An important condition placed upon the author was that no shot should be fired after eleven P. M. This may have delayed the time in finishing the tunnel, but did not, in the author's opinion, increase the cost of the work. If anything, it resulted in a saving. The following plan was adopted after careful consideration. One gang was required to drill and fire before leaving; then one man in each heading was required to dig it out and have it ready for the gang to drill the next day. The average time on each heading was thirteen hours. As it would have taken, on the average, from four to five hours to clean out the heading and set up the column ready for drilling, and only one man could work at the face to clean it out, in two complete gangs about ten hours would have been lost in each twenty-four hours.

The diameter of the holes was $2\frac{1}{4}$ inches to commence with, and $1\frac{1}{2}$ inch in the bottoms. The holes were drilled in the following order: Two dry holes in the roof, three in the next row, four in the third row five in the fourth row, five in the fifth row, and three in the bottom. Sometimes an extra hole was drilled, starting in the centre of the fourth row, and landing between the fourth and fifth rows, to make sure of getting the cut or key out. If this came out all right, there was very little trouble in getting the rest out. It may be interesting to know how the holes were drilled. Assuming the drill column is set in the centre of the tunnel or heading, the drill being about in the centre of the arm, commence by lifting the arm and drill as close to the roof as possible, inclining the drill upward about 6 inches. This hole, as stated before, is drilled dry. After this is finished, the drill standing the same on the arm, tip up the machine, starting about 10 inches or a foot below the roof hole, drill one in the centre, then move out on the arm to the end, and drill a hole on the side almost straight ahead; then drop the arm on the column

about 14 inches, tip the drill up about 3 inches more than for the last row, and inclined outward about 7 inches. Now shift to the centre of the arm and drill a hole straight, starting about 1 foot from the side hole, then tip up 10 inches more, the arm and the drill remaining the same, and drill a hole directly under the last one ; then start a hole about 6 inches from this at the same dip, but running across the centre of the heading and to a point about 6 inches on the other side of the column ; then move to the end of the arm and drill a side hole inclined about 7 inches as before stated : then drop down on the column, within about a foot of the bottom, and drill three holes similar to the last three ; then drop to the bottom and drill one in the centre and one on the side. This completes the drilling on one side of the column. Next move to the other side of the column, and drill a roof hole as before ; then tip up about 10 inches and drill a side hole as before; then drop down 14 inches, and drill two holes ; then tip up 10 inches, but drill only two in this row, there being three on the other side : the next row is drilled like the last ; then one in the bottom, completing the heading for blasting.

The blasting proceeded as follows : From two and one-half to three pieces of Atlas powder A brand, supposed to be seventy-five per cent. nitro-glycerine, were put in two holes in each of the rows having five holes in it: these four were fired first · then two on each side of these ; then the two left on the side ; this would remove all the rock in this section of the heading from one side to the other. By the next blast the three holes in the bottom were blown up and the row of four holes was blown down ; after this the row of three holes, and the upper row were blown downward by separate blasts. One A and one D cartridge was generally used in each hole after the cut was out. These cartridges were 6 inches long and 1¼ inches in diameter. The powder smoke was troublesome, but there were no serious results ; the author himself was overcome several times The effect of the powder was overcome by inhaling ammonia which was kept in a bottle at the shaft, and was used by the men. On the last 100 feet Forcite powder was used. It made more smoke than the Atlas powder, but none of the men were affected by it as by the smoke of the Atlas powder, and it certainly gave better results. About one in six of the cut shots gave trouble with Atlas powder, and only one in twenty with the Forcite powder.

The cost of shaft sinking averaged about $3.00 per foot of tunnel, the miscellaneous items $1.00 per foot of tunnel, and the brick-work about $4.00 per foot of tunnel, the tunnel $17.25 per foot, making in all about $25.25 per foot for the tunnel completed. Add to this $4.00 per foot for the surface sewer, which is a liberal allowance, makes a total of $29.25 per foot of sewer completed. The two sections in open cut averaged $15.00 per foot without the surface drainage, including about 8 feet of rock. From the indications at each shaft, the rock would have averaged 26 feet in depth, and at the slow rate that must have followed, the cost could not have been much less than fifty or sixty dollars per foot.

About eighteen hundred pounds of dynamite were used with no serious accident to any man on the work. This the author considers very remarkable for such an undertaking.

The material was moved in wheelbarrows to the shafts, hoisted in

buckets holding about four cubic feet, or two barrows, landed on a truck on the surface and run to the dump, while another was hoisted.

A simple arrangement for head gear was made thus: two pieces of 6-inch by 6-inch about 20 feet long placed 3 feet apart and spanning the shaft, held in place with two struts toward the engine and provided with an iron strap to hold the block. It was a very simple affair, cost little and answered its purpose very well.

The tunnel was kept dry with two Knowles pumps, with 2-inch suction and 1½-inch discharge, run by the hoisting boilers. Sometimes a double engine was used which took care of two shafts.

The tunnel was lined on the lower half with brick-work: the top was left with a rock face. Only two small sections of the tunnel had to be arched with brick in the rock excavation.

The lines and grades were given by Mr. Forbes, Assistant Engineer. No error could be discovered at the junctions of the several headings. The alignment was carried on the surface with an ordinary transits, with two ten-pound plumb-bobs at the shafts, and in the tunnel between with a fine line, which worked very well.

ELIMINATION OF ERRORS IN FIELD WORK.

By Wm. Bouton, Member of the Engineers' Club of St. Louis.

[Read January 21, 1885.]

Accuracy is a relative term. "We speak of a thing as accurate with reference to the care bestowed upon its execution, and the increased correctness to be expected therefrom" (Webster's Synonyms). It would not be accuracy but confiscation to expend the same amount of painstaking labor in surveying land worth one dollar and a quarter an acre that would be essential in surveying town lots, where the walls of valuable buildings abut with precision upon the property lines. The purpose of the work determines the method which should be used, and the amount of human frailty which may receive the award "well done." Old surveys are often retraced by the methods originally used, and are found accurate, *i. e.*, without mistake, and with a care adequate to the use for which the property is fitted. When the use changes, and with it the method of surveying, it is probable that every line will have a revised and corrected length, every angle a different observed value. A surveyor engaged in such work is trying to find out how much the ground has grown since it was measured last. Mr. Culley (see the Journal of September, 1884), makes an earnest appeal for the transit and steel tape for farm surveying. When the course of the survey strikes into ground that is covered with briars and hazel brush, honey locust and poison oak, grapevines and other vines too numerous to mention, with weeds ten feet high wherever they can get breathing room, I confess that for my part I prefer the compass and chain, and consider that method entirely adequate until the land can be put to some better use; but if the land is well cultivated and the fence rows are clean, it is practicable to use the transit and tape

without much extra cost and with very much more satisfactory results. It is generally true that the earliest application of more accurate methods finds, before the work can proceed, more rough places to be made smooth, than crooked places to be made straight. The best work cannot be done under such circumstances; while human nature stops short of absolute perfection, the quality of the work, of those who are competent and careful, will be affected by conditions under which their work is done. To him who makes the elimination of error from his own work a labor of love, or a matter of professional pride, it will soon be plain that every kind of error, which can in the nature of the case possibly exist, will some time be found, that the simplest kinds of work involve many possibilities of error, and will further find that every check introduced into the work in order to prevent error, brings in its train new possibilities of error.

If the problem is to retrace an old survey, having the original notes, a comparison of the resurvey with the original will probably show errors in one or the other, which may be classified as follows:

1. Errors due to difference of method used.
2. Errors due to the extent of the work and to the passage of obstacles.
3. Errors in the work or record due to the incompetence or carelessness of either surveyor.

These observed errors are the algebraic difference of errors, kind for kind, of the two surveys. The true values are not to be reached by a division of the observed errors, nor by the assumption that they all belong to the older survey. Approximation to the truth is to be sought for in the increased care given to resurveys.

When a survey takes the form of a subdivision with a recorded plat, and deeds are made referring to the plat of record, the number of possible errors is very much increased. In making a subdivision no pains should be spared, (here virtue brings its own reward, if not to the surveyor, at least to the community); the plat should be mathematically consistent, and should correctly show how the subdivision stands related to original property lines; monuments marking the more important points of subdivision should be accurately placed upon the ground. Angles as well as lines and distances are an essential part of a workmanlike plat. The ideal subdivision is seldom seen. On the other hand, the number of hairs in a man's head would all be needed, if he should attempt to keep tally with them in how many ways a subdivision, or its recorded plat, or the corner stones may be wrong.

Next comes the conveyancing built upon this foundation. An ingenious notary can make things lively for a surveyor; the half was never told.

The field notes purport to give an account of how the corners have been perpetuated, what marks now exist and how the subdivision has been verified by resurvey. If they fail to give this information, that failure is often a source of error.

The place where most of the errors so far noted should be corrected is in the office, but the place where they will materialize, if not corrected, is in the field. They form the vast majority of the reasons why "two

surveyors can never agree." A judiciously arranged and thoroughly equipped office is an essential precedent to correct field work, and makes many things possible which, without it, are impossible.

There are surveyors who say, "I don't go into any such questions. I survey what is ordered. If a man brings his deed to me, and says, 'I want this lot surveyed,' and that deed contains a description which can be located, I follow it; if it contains other words and phrases which presumably mean something, but what they mean is uncertain, I ignore them—all that belongs to the investigator of titles."

Suppose that this statement is made to the owner of the lot, and he says, "Yes: I had the title investigated, here is my abstract." You take it, and read the description in the deed, possibly with the puzzling phrases omitted, and a certificate like this: "I have examined the public records of X county, and the indexes thereto attached, and find the title to the above-described lot fully vested in John Smith: taxes paid: judgments, none," you don't feel that you have learned much: but if you inquire further, the investigator will tell you something like this: "The *chain of title* is complete from the original owner to the present. The conveyances are in due form." "But," you ask, "what is the force of this call for boundary?" or this: "And being the same property conveyed by deed of Brown to Jones?" He may reply, "The wording of that deed from Brown was a little different from that of the present deed; but it is not such a difference that I can sit here in my office, and, looking at the two papers, say that they must mean different things; that is a *question for surveyors*. As to that 'boundary,' I was investigating Smith's title, not his neighbor's." Between such investigators and such surveyors and notaries, who are willing to add or omit a word or phrase in order to make the meaning as they understand it plain, there is many a stitch dropped. Neither can keep closely to what he is pleased to term his own business and give a final result free from mistakes. If there be a mistake in some such way caused, whose fault is it that the location is wrong? Generally, I think, the surveyor's. He is employed to correctly interpret the meaning of that deed by marks upon the ground. It is his business to get, and require pay for getting, in some way the information necessary in order to do the work. Interpretation presupposes understanding; it will not do, while a part of the deed is in doubt, to interpret what is plain and say, "This is all." Some State law-makers need to learn this lesson.

If the work so far described has been well done, the field work is next in order. The location of a line is the accurate determination and marking of its origin, direction and length. There is a trite saying, "If surveyors could only agree on what they should measure from, the rest of the differences would be of little account." While there is something to be said as to other differences, after this branch of the subject is finished, I feel compelled to admit that there is a deal of force in this view. It involves the perpetuation of lines by all the methods known to the craft, and the verification to-day of that which survives from the past. In a majority of instances in this city the deeds recite that the property sold is a part of —— Subdivision, as per plat of record. The recorded plat usually does not show how the lines were marked; does not

even show that they were ever marked at all. Nevertheless it is fairly probable that stones or other monuments have been set. What is now the proper thing to do? Shall I agree with Pope that, "whatever is, is right," and take unquestioning that which first comes to hand and make from it the required location? If so, my neighbor who has an office across the street, may with equal right measure from the other end of the block and certify my survey wrong. Monuments derive their authority, not from the fact that they exist, but from the fact that they conform with reasonable accuracy to the recorded plat. To say that the location of the subdivision logically precedes the location of lots within it, is but another way of saying the same thing. It is the surveyor's business, not to assume, but to know with reasonable, or at least with all attainable certainty, that the monuments found correspond to the subdivision. Having once verified carefully the position of corner stones, or whatever else approximates permanence, that position is for the future a matter of knowledge. But the *permanence* of all marks whose position is essential to the survey must whenever used be tested before a location is made.

Although much field work has been implied in what has been already said, the discussion of methods of measuring has been left until more important things were disposed of; no care in determining the length of a line can make that survey correct which begins in the wrong place and ends nowhere.

Considered as affecting the result, errors are plus or minus. Some of the sources of error which affect every piece of work are as likely to produce plus as minus errors, and will, in fact, produce both plus and minus errors in the same piece of work, *e. g.*, inaccuracies in observing the point of a plumb, or its vibration in a still day. The theory of probability shows that if the number of trials is made sufficiently large the number of times when each possible event will occur will be in precise proportion to the probability of that event. If the errors due to any source are as likely to be plus as minus, the relative resultant error will become less than any assignable limit, as the extent of the work approximates infinity. Experience will enable the surveyor to fix upon the value of the maximum error in his own work for a short distance, say 100 feet. The maximum possible error is a simple multiple of this, and it is something approximating this maximum occurring at improbable and unexpected times that plagues and costs reputation at least. I have found no better way of eliminating this possibility than by measuring and running general lines, such as boundaries of the larger tracts, then cutting up the area by intersecting lines and tying up every survey at both ends.

Other sources of error are in their nature not compensating but cumulative. The ideal surveyor applies such a correction as to make every cumulative error compensating. In the free-hand work of the surveyor, any cumulative error, if platted in terms of the distance measured, would show a wavy line; a correction of its averge value would leave a compensating error—a sort of second differential. I proceed to consider some cases.

Within the last twenty years the old method of using wooden rods when accurate measurement was desired has been with great advantage

replaced by the use of the steel tape. The surveyor professes to give the horizontal distances between points noted. A man measuring with a tape never measures a horizontal distance. What he does measure is a succession of catenary curves. Men who ought to know better have suggested that this may be all very true, but it don't amount to much anyhow. I suggest the following as worthy of notice. Any curve is longer than its chord; it is also longer than the sum of the two chords which join its ends with its middle point. If the tape used is fifty feet long, and the sag at the centre is one half a foot, the short chords diverge from the long chords at the rate of two feet in one hundred. A moment's inspection of a table of cosines will show that the sum of the short chords exceeds that of the long chords by more than one foot in a mile. I consider that this approximate error from one source is greater than the sum of all the errors which a reasonable man surveying city lots should admit into his work. The case demands attention.

The following table I have found convenient in my own work and submit for what it is worth. Taking the condition that the tape is of uniform section and carries no load except its own weight, I use the following nomenclature:

H = horizontal tension.	s = length of curve from origin.
w = weight of unit of length.	l = length of tape.
W = weight of tape.	x and y = horizontal and vertical co-ordinates, origin at lowest point.
e = base of Naperian logarithms.	

$$\text{Then } y = \frac{H}{2w}\left(e^{\frac{wx}{H}} + e^{-\frac{wx}{H}} - 2\right), \text{ and } S = \frac{H}{2w}\left(e^{\frac{wx}{H}} - e^{-\frac{wx}{H}}\right).$$

Observe that if $\frac{H}{2w}$ is constant, y and s constant, for $x = \frac{1}{2}l$.

For assumed values of this ratio varying between sufficiently wide limits, the effects of the sag and of the corresponding pull are tabulated. When the sag is observed the errors shown are correct, the pull need not be observed, and the tape may be heavy or light. If an engineer prefers to estimate or measure his pull rather than his sag, let him divide his pull by the weight of his tape and seek the quotient in the fourth column and the corresponding error in the sixth or seventh. I add the second part of the table for such as prefer a tape 100 feet long.

x = 25 FT. TAPE 50 FT. LONG.

Sag.			Pull.		Resultant ±.			
					Error in 50 ft.		Error in 1,000 ft.	
$\frac{H}{w}$	y	Excess of curve. − error.	$\frac{H}{W}$	Elongation + error.	−	+	−	+
	Ft.	Ft.		Ft.	Ft.	Ft.	Ft.	Ft.
400	0.78	0.0326	8	0.0025	0.0301	....	0.602	....
500	0.63	0.0200	10	0.0031	0.0169	....	0.338	....
600	0.52	0.0140	12	0.0037	0.0103	....	0.206	....
700	0.45	0.0098	14	0.0043	0.0055	....	0.110	....
800	0.39	0.0071	16	0.0050	0.0021	....	0.042	....
900	0.35	0.0055	18	0.0056	....	0.0001	....	0.002
1,000	0.31	0.0045	20	0.0062	....	0.0017	....	0.034
1,100	0.28	0.0040	22	0.0068	....	0.0028	....	0.056
1,200	0.26	0.0037	24	0.0075	....	0.0038	....	0.076

$x = 50$ FT TAPE 100 FT. LONG.

Sag.			Pull.		Resultant ±.			
					Error in 100 ft.		Error in 1,000 ft.	
$\frac{H}{w}$	y	Excess of curve. − error.	$\frac{H}{w}$	Elongation + error.	−	+	−	+
	Ft.	Ft.		Ft.	Ft.	Ft.	Ft.	Ft.
800	1.56	0.0652	8	0.0099	0.0553	....	0.553	....
900	1.39	0.0509	9	0.0112	0.0397	....	0.397	....
1,000	1.25	0.0400	10	0.0124	0.0276	....	0.276	....
1,100	1.14	0.0334	11	0.0137	0.0197	....	0.197	....
1,200	1.04	0.0279	12	0.0149	0.0130	....	0.130	....
1,360	0.96	0.0234	13	0.0161	0.0073	....	0.073	....
1,400	0.89	0.0196	14	0.0174	0.0022	....	0.022	....
1,500	0.83	0.0166	15	0.0186	....	0.0020	....	0.020
1,600	0.78	0.0142	16	0.0199	....	0.0057	....	0.057
1,800	0.70	0.0109	18	0.0223	....	0.0114	....	0.114
2,000	0.62	0.0090	20	0.0249	....	0.0159	....	0.159
2,400	0.52	0.0074	24	0.0298	....	0.0224	....	0.224

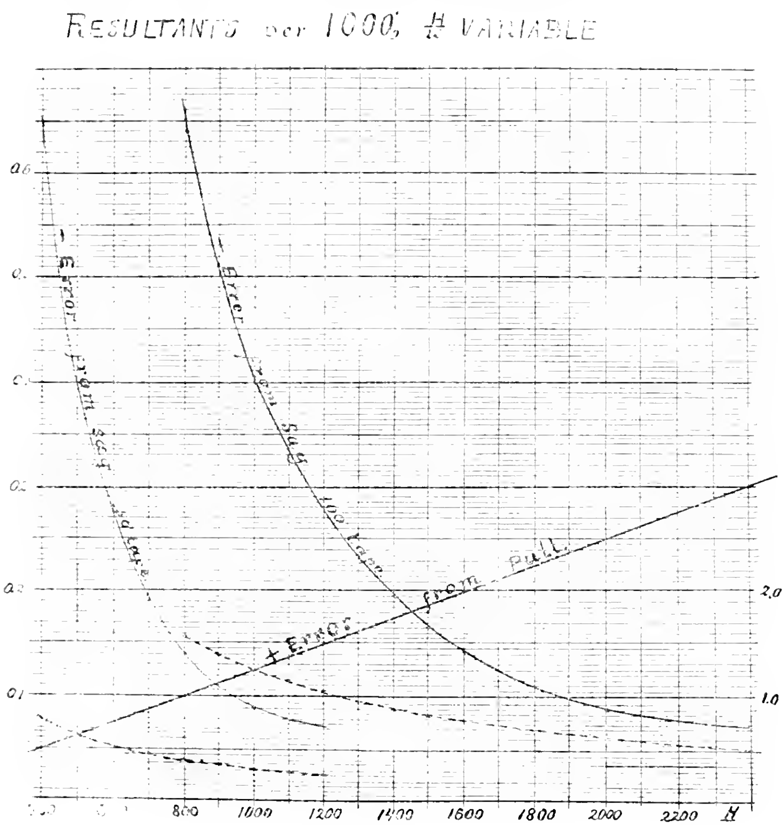
In the formula elongation $= \frac{P\,l}{E\,k}$, $\frac{P}{k}$ is a multiple of $\frac{H}{w}$ in the first column of the table. Hence the elorgation varies as $\frac{H}{w}$. I have used $w = 3.4\,k$ for tempered steel. A change in E, modulus of elasticity, would change the fifth column and all derived from it.

I do not think there can be a difference in tempered steel reduced to so small a section as a tape which will be of sufficent importance to be taken account of in surveyors' work. Professor Johnson, of our club, made, in 1881, for the United States, a series of experiments upon a Chesterman 300 feet long; he found $E = 27{,}400{,}000$. I have used his coefficient. I see Mr. Culley uses 29,000,000, but cannot find any reason to suppose it has better authority. It would appear from the table that it is practicable to pull such an amount that no correction need be applied for these errors. Experience will show, however, that, if the habitual pull is right for a perfect calm, the slightest wind will carry out the centre of the tape to fully one-half a foot sag, without being sufficient to suggest the necessity for increasing the pull in order to reduce the sag.

The accompanying sketch shows graphically the same facts. The sag, in dotted lines, scale at the right, is for a single length of tape. The full lines, scale at the left, show the resultant errors for one thousand feet, and can at any point be read as accurately as the average sag can be observed. Perhaps better say, as accurately as average observation can determine sag, for the sag should be as constant as a consciously constant pull can make it. The observation is the surveyor's means of knowing that the work is being done. A more emphatic statement than the sketch itself of the worthlessness of an unsteady hand at the forward end of the tape would be hard to make.

A second reason why surveyors do not measure horizontal distances is that the ends of the tape are not kept level. If a man says " I can do it," watch him closely, for when he succeeds it will be a mistake. If he says " I can come pretty near it," give him credit for understanding the situation and watch him too. There is a difference of ability to judge,

but at some point every person would recognize such an error. In this case we have the joint judgment of at least two men presumably somewhat experienced. The limit of their error will be approximately uniform for like conditions; probably will not exceed two per cent. of the length of the tape. We may suppose that no error in judging the level exceeds two per cent., and assuming a probable distribution of errors within that limit calculate the probable correction, but the result is too small to account for the facts. A surveyor of any experience knows that somehow or other this correction must sometimes amount to con-



siderable. On lines where appearances are deceiving, it is customary, when there is a difference of opinion, to test the matter by plumbing a different hight, and correcting the pin, if an error is apparent. Now this method of correction is not applicable to errors of inclination, which are smaller than two per cent., and some which are larger than that will slip through. On some lines this check is necessary every time for a large part of the distance. On such lines the head is no longer level; the apparent horizontal differs from the truth, and the probable range of error instead of being equally each side of the horizontal, is all one side,

and may be at its limit nearly five per cent. The part exceeding two per cent. may be very nearly all eliminated by the method noted above. I conclude that there is *always* an error due to the fact that the tape is not horizontal, and this is always a minus error. A constant correction for it and for the resultant between sag and pull should be determined by the surveyor for his "team," and applied to sticking of the pin. A further minus correction is due this cause on difficult lines, before it should be called a mistake: at its extreme limit I place it at two-tenths of a foot in one thousand feet—the correction due to an inclination of two per cent. This further correction should never be applied to *graded* lines, for there such an error is inexcusable.

"Were it not for variations due to temperature," Mr. Culley says, "all lines, both long and short, within the scope of the land surveyor, could be measured exactly." The idea of dating a survey in order to be able to judge of the probable error due to this cause, which he suggests farther on, may do in Cleveland; but in a climate which boasts of 80° F. in January, and 60° F. in July, with a wide range of temperature in any month, this method of eliminating the error is fallacious. The plus and minus maximum errors due to this cause are very large: but the easiest in the whole list to manage. I attach a thermometer to my transit so as to carry it conveniently, observe the temperature in the sun or in the shade, according to the average condition of the line, and make the correction then and there.

The standards furnished by the government are rods of steel correct at 60° F., or as marked. Using these, a rod of steel as long as the tape used should be marked with the standard length at 60° F. This standard, for obvious reasons, should be sheltered from sun, wind and rain. If an office floor is long enough, it will furnish a convenient place for fixing it. The centre should be held firmly, and the ends be so fastened that they may expand freely, but cannot be bent or sprung out of place. The marking should be done after it is in place. A tape tested on such a standard is correct at 60° F., whatever may be the temperature when the test takes place, provided that the tape be brought to the *same temperature* as the rod before the test is made. All measurements should be made with the tape at its tested length, and the correction applied to the whole distance measured. Some tapes are made so as to apply the correction to the tape. I have tried both ways, and don't want any adjustable tape in my work. A thermometer is equally necessary, and one more loose end is to be watched with no corresponding advantage.

I have found this table useful on a fly leaf of my field book:

— ERRORS.

Deg. F.	100′	200′	300′	400′	500′	600′	700′	800′	900′
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
5	0.042	0.084	0.126	0.168	0.210	0.252	0.294	0.336	0.378
10	.035	.070	.105	.140	.175	.210	.245	.280	.315
20	.028	.056	.084	.112	.140	.168	.196	.224	.252
30	.021	.042	.063	.084	.105	.126	.147	.168	.189
40	.014	.028	.042	.056	.070	.084	.098	.112	.126
50	.007	.014	.021	.028	.035	.042	.049	.056	.063

ERRORS

70	.007	.014	.021	.028	.035	.042	.049	.056	.063
80	.014	.028	.042	.056	.070	.084	.098	.112	.126
90	.021	.042	.063	.084	.105	.126	.147	.168	.189
100	.028	.056	.084	.112	.140	.168	.196	.224	.252
110	.035	.070	.105	.140	.175	.210	.245	.280	.315
120	.042	.084	.126	.168	.210	.252	.294	.336	.378

There is nothing new in it, but it is better to do a simple thing right once for all than to be doing it over and over again for all time.

The force of the wind upsets all these calculations. Our catenary curve that was a function of x and y, is now a function of x, y and z. The plumb ceases to point to the centre of the earth. Its average position is misleading—is the result of a composition of forces. These effects can be mitigated to some extent by holding the centre of the tape to its place in line, by shielding the plumb and increasing the pull: but such work is always unsatisfactory. The only way to eliminate this source of manifold errors is to cease from any piece of work when the wind is so high that it cannot be done as it should be done. There are estimates, topography, etc., which do not require a high degree of precision and can be done when other work cannot.

Subdivision work, where it is proposed to build brick walls to property lines, showing errors in closing or subdivision of 1 in 5,000, should doubtless be retraced. The average error of resurveys, built on such a basis, need not exceed 1 in 20,000. The maximum error can then be kept within manageable limits.

OLD BRIDGES UNDER NEW LOADS.

BY C. M. BARBER, MEMBER OF CIVIL ENGINEERS' CLUB, OF CLEVELAND.

[Read December 8, 1885.]

From a railroad stand-point, if not from every other, we are living in an age in which kinetic energy seems to take the lead. The wheels of commerce are to-day turning faster than ever before. The watchword of the hour is "rapid transit." Whether this is due to the natural and healthy development of an enlightened civilization, or to the feverish excitement of competing monopolies, or to both, it matters not; the fact remains.

The great improvements in automatic brakes have made it safe to run express trains at almost the highest attainable speed, and we think it will not be long before a like improvement, applied to freight cars, will make it practicable to run heavy freight trains at a considerably increased speed, especially certain classes of freight.

With the same end in view, the loads and empty weights of freight cars have recently been greatly increased, and locomotives, such as George Stephenson could hardly have dreamed of, are in common use.

It is the purpose in this paper to call attention to the fact that since the

weight and speed of the rolling stock have been and are now being rapidly and greatly increased, substructures that have not been especially increased in strength and stiffness to correspond to the additional loads put upon them are subjected to greater strains than those for which they were designed: also to show the effect of greater loads at increased speeds on such structures.

If we compare the present weight of a freight locomotive or of a passenger locomotive with that of ten years ago, we shall find that there has been an increase of about 50 per cent. "The capacity of cars has increased from 20,000 pounds in 1855 to 1876, to 40,000 pounds in 1882, and to 50,000 pounds in 1885; and the master car-builders have recently decided upon a standard car to carry 60,000 pounds. The weight of cars on the Pennsylvania Railroad increased from 20,500 pounds to 22,000 pounds only, from 1870 to 1881." We extract these facts from Mr. Corthell's valuable paper, read before the American Society of Civil Engineers June 25, 1885. This gives us for the total weight of loaded cars in 1876, 40,500 pounds, in 1885, 72,000 pounds, thereby showing an increase in the weight of loaded cars of 77 per cent. in 9 years.

Railroad truss bridges in this country are of three kinds, viz: wood, iron and combination. The usual form of the last two is the Pratt truss, (as it is generally called), but the first is nearly always of the Howe truss form.

The Railroad Commissioners report of Ohio shows that there were in use in this State:

	Wooden.	Iron.	Combination.
In 1882	936	347	81
In 1883	1,165	461	134
Number built in one year	229	114	53

From this table we see that the old reliable of our fathers, the wooden Howe truss, is still on duty with a large majority. The Howe truss is undoubtedly the most economical wooden bridge that is built. It was invented in 1846, but was then built with an arch, which we think is never seen now, except where it has been put on afterward as a re-enforcement.

The iron bridges in common use are generally of the best construction, and most are now new and up to the present standard, but some of the older ones are being, or should be, replaced by heavier ones.

Without further considering the different forms of trusses, let us examine the chord strains of any of those in common use. In any form of truss there is a tension strain in the lower chord and a corresponding compression strain in the upper chord. These chord strains are at a maximum when the entire span is loaded; and if we take the load as uniform, the maximum strain will be at the centre, and arises from the maximum bending moment being at this point. If we divide this bending moment by the depth of the truss, we shall have an expression for the maximum strain in either chord, viz: chord strain $= \frac{Wl^2}{8d}$; in which W is the sum of the dead and live loads per foot, l the length and d the depth of truss. If we take from the 1876 edition of Trautwine the dead

load he gives for a span of 130 feet, and assume a live load of one ton per foot, we have:

		Pounds.
Dead load per foot per truss	....	643
Live " " "	....	1,120
	W	1,763

Assuming the depth of truss at twenty-two feet and substituting in the above formula we have:

$$\text{1st. Chord strain} = \frac{Wl^2}{8d} = 169{,}288 \text{ pounds.}$$

Again, taking the same dead load and a live load as used in 1885, we have.

		Pounds.
Dead load per foot per truss	....	643
Live " " "	....	1,560
	W =	2,203

$$\text{2d. Chord strain} = \frac{Wl^2}{8d} = 211{,}538 \text{ pounds,}$$

which value is 25 per cent. greater than the first.

If, now, we take the live load, as used in 1885, and a dead load corresponding to it, we shall have:

		Pounds.
Dead load per foot per truss	....	1,200
Live " " "	....	1,560
	W =	2,760

$$\text{3d. Chord strain} = \frac{Wl^2}{8d} = 265{,}022 \text{ pounds,}$$

which value is 56 per cent. greater than the first.

Since the dead load of an iron bridge is about the same as that of a wooden one of the same strength, we see that bridges of about 130 feet span, built according to an approved standard in 1876, if now in use are overstrained 25 per cent.; and since the material in a tension member is directly proportional to the strain, we see by comparing the strains obtained from equations 1st and 3d that the lower chords are deficient about 50 per cent. It will be observed that the live loads in the examples above differ only about 40 per cent.

There is not an engineer here to-night who cannot call to mind many railroad bridges, that are now in use exactly as they were 10 years ago, and, that are now carrying 50 per cent. more load than they were designed to carry. It is a well-known fact that there are many new wooden bridges now in use, that are copies of those which they replace. The effect of this is that while our engines and cars have been greatly improved, the road-bed is deficient and behind the times.

The master mechanics tell us that locomotives are now sufficiently perfect for a speed of 60 miles per hour, but the road-bed is not equal to it. We will not question the perfection of the locomotives, at least not at present, for we know that the point is well taken. The road-bed is not equal to a speed of 60 miles per hour.

Let us for example examine the effect of an ordinary load moving at an ordinary speed, on a bridge that is only deficient enough to deflect a

little more than the camber in the track. An engine weighing 140,000 pounds moves at the rate of 64.4 feet per second (equal to about 44 miles per hour) over a bridge 128.8 feet long. Let us assume that the bridge deflects 0.166 feet, or 2 inches.

In figure 1 let $A\ C$ denote the length of the bridge, $B\ D$ the maximum deflection, and α the angle $B\ A\ D$; suppose the engine to move along the line $A\ D\ C$, moving from A to D in one second. Then the mechanical effect on the bridge may be expressed by the formula

$$E = 2\,\frac{v^2}{2g}\,W \sin.\ \alpha,$$

in which v equals the velocity, and W the weight of the engine. Substituting in the formula the above quantities we have,

$$\text{Mechanical effect} = 2\,\frac{(64.4)^2}{2\,g}\ 140{,}000 \times .002588 = 46666 \text{ foot pounds.}$$

Now, of course, the engine will not move along the line $A\ D\ C$, as in figure 1, but will take a line more like figure 2, or possibly like figure 3.

FIG. 1

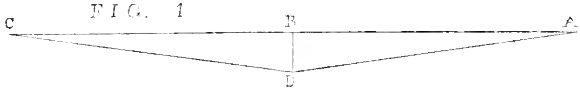
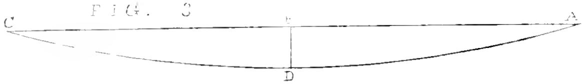


FIG. 2

FIG. 3



In either case it is evident that the mechanical effect will be equal to or greater than if the engine took the line as in figure 1. An examination of this equation will show E to be directly proportional to the square of the velocity, so that if we double the speed, the mechanical effect will be multiplied by 4, etc.

Also E is directly proportional to the weight. Also that E varies directly as the sine of α; but sine α is inversely proportional to the length of the bridge, so the mechanical effect is inversely as the length of the bridge.

We might also note that E varies directly as the deflection.

In order to appreciate this mechanical effect we might observe that 46,666 foot-pounds is equivalent to a weight of 140,000 pounds falling 4 nches, or to a weight of one ton falling 23 feet, or to ten tons falling 2.3 feet, etc.

If the bridge deflected only one inch we should then have a mechanical effect equivalent to 140,000 pounds falling 2 inches, or five tons falling 2.3 feet, etc.

Of course, we must note that this mechanical effect is not concentrated on any one point, neither is it uniformly distributed.

Now if we consider that the speed of trains has increased, in ten years,

from 35 miles per hour to 49½, from 30 to 42.4 and from 15 to 21.2; then the mechanical effect on any bridge, of any deflection, or on any bridge having either too much or too little camber, is now double what it was 10 years ago, since the squares of the above speeds are as 1 to 2. If we also consider, in addition to the above, that the moving loads have been increased 50 per cent., then the mechanical effect has been multiplied by three.

We think it may very properly be asked, what static load would produce the same strains on the members of the bridge as the strains due to this mechanical effect; for are not all our calculations on bridge strains in vertical trusses based upon static loads? On this point writers on mechanics are silent, or they tell us that the pressure between a pile driver and a pile cannot be calculated. This is, however, a different case, and suggests a field for experiment and investigation.

As the result of a long series of deflections applied to an experimental plate girder of 20 feet span, Mr. Fairbairn concludes that a bridge subject to 100 deflections per day, each equal to one-third of its extraneous breaking load, would probably break down in about eight years; while with 100 daily deflections, equal to that arising from but one-fourth of its breaking load, it would last fully 300 years. But Mr. Fairbairn's experiments are so foreign to the case in hand that they throw but little light upon the problem. There is, in addition to the mechanical effect produced by the load, a mechanical effect due to the motion of the structure itself; but this effect is most powerful when we consider the rapid vibrations, which are generally small. We wish to say that we do not believe in the violin bridge tradition, unless the player were taking his first lessons; in that case we have nothing to say.

We think it is generally conceded that the permanent way on most of our roads is sadly deficient, or else we are running too heavy rolling stock. Every year we see heavier engines and cars of greater capacity rolled out upon a track that did not know they were coming. We think it is time for builders and maintainers of permanent way to bring their work up to the standard of the rolling stock. There are roads, as, for example, the N. Y., P. & O., where every Howe truss has been either reënforced or taken down and replaced by iron within the past six years. There will be a railroad, and that, too, in a few years, on which the substructures, as well as the rails and ties, will exceed in strength, stiffness and stability any railroad ever built, and on it ships weighing 6,000 tons will travel from ocean to ocean.

TOPOGRAPHIC SURVEYS OF STATES.

By H. F. Walling, Member of the Boston Society of Civil Engineers.

[Read February 17, 1886.]

The initiation of coöperative State surveys in this country having inaugurated a new departure in topography, a complete history of previous efforts in this work throughout the country would have a special interest at this time. Not having the requisite data, however, I can only speak of them in a brief and imperfect way.

Up to about 1850, such maps of the older States as had been published were nearly all made at the cost of the respective State governments, or were liberally patronized by them. This was the case in New York, Pennsylvania, Maryland, Virginia, Georgia, Alabama and Mississippi. The maps of these States were in general compilations from the plans of original land surveys. In 1844, Massachusetts caused to be published an exceptionally good map of the State, from special surveys made at the cost of the State and of the several towns. The geodetic basis of this map was the triangulation of Mr. Simeon Borden, and, as you are aware, it was a very well executed work. The details of topography, however, were worked out by the local town surveyors, whose methods, as might be supposed, were incongruous and generally defective, producing results which fell very far short of the precision which accompanied Mr. Borden's work. In spite of this imperfection, however, the map as then published far excelled any other State map in general accuracy and completeness of detail, nor does it suffer, considering the difference of scale, in comparison with the original Ordnance map of England. From the year 1850 up to the commencement of the civil war in 1861, and for some ten or twelve years after the close of the war, the demand for maps giving more local details than had been shown upon previous maps became sufficient to induce surveyors to engage in their publication, a portion of the expense being in some cases defrayed by State, county or municipal appropriations. Maps of towns and counties, afterward compiled into State maps, were made in this way, almost entirely from original surveys, in all of the New England States, New York, Pennsylvania, Ohio and Maryland. Large maps of some of the States west of Ohio were also published from time to time. Since the construction of these Western maps consisted principally in compilation from the United States Land Survey plans, the labor in preparing them was much less than in the Eastern States.

Commercial Maps.—Maps made with no means of defraying the cost other than from proceeds of sales have been styled " commercial maps," in distinction from maps produced at the cost of Government, the surveys for which are sometimes called " scientific surveys;" but I think the propriety of the designation is, in some cases, questionable. A survey may present the general features of the country with a considerable degree of accuracy, but if the details are erroneously represented in important respects, it is manifestly an incongruity to denominate such work a scientific survey. A comparison of some of the Government surveys of Western territorial regions, where two independent surveys overlap each other, proves by their discrepancies the inaccuracy of one or both the surveys. On the other hand, comparisons of some of the commercial maps with subsequently published Government maps, shows close correspondence, and as there is no reason to suppose that the latter are copied from the former, it follows that even a commercial map may be worthy of credit so far as it goes.

It should be observed that until quite recently *all* of the maps heretofore published in this country, whether by the Government or by individuals, with a very few exceptions, are destitute of accurate hypsometric information. The more notable exceptions are the topographic work of

the United States Coast and Geodetic Survey, of the United States Geological Survey, principally in the Western territories, of some mining engineers who have made admirable maps showing portions of the anthracite coal fields of Pennsylvania, and of the Second Geological Survey of Pennsylvania in special maps of limited areas in that State.

The wholesale condemnation which certain scientific critics have from time to time bestowed upon commerical maps, as such, not discriminating between those which have been carefully made from original work and other mere compilations from Government explorations, etc., which perpetuate from year to year the original errors of their sources of information, indicates an unjustifiable lack of knowledge on the part of the critic, of the amount of original and really valuable information which some of these commercial maps embody. They have rendered valuable service to railroad and hydraulic engineers, to county and town officers, and even to geologists and other naturalists and scientific investigators. Besides these, many intelligent citizens, realizing the value of the maps for their own more private uses, have, by bestowing their patronage upon the surveyors, enabled them to publish these maps. If competent experts found on examination that these maps were erroneous and unworthy of credit, it would be their duty, in behalf of the public, to expose their unworthiness by pointing out the inaccuracies, etc. But it is hardly justifiable to condemn them *en masse* merely on account of their self-sustaining origin or because the mechanical execution was not upon so expensive a scale as might have been possible under more favorable conditions. My apology for bringing this somewhat unprofessional subject before the Society is a feeling that injustice has been done to a number of local map makers in the New England and Middle States, who at their own cost and risk, during the last thirty-five years, have materially added to the previous knowledge of local topography, so far, at least, as it pertains to horizontal relations.

County Maps of Massachusetts.—I now beg your further indulgence for a brief account of some of the methods employed in my own work in Massachusetts some thirty years ago. This is done principally for the purpose of showing what can be accomplished at a comparatively small cost. It is not cited as an example to be followed, but rather as one whose faults and shortcomings are to be avoided when the means of carrying on the work in a better manner are available.

Having previously made surveys and maps of a number of towns and cities in the State, which were generally paid for by municipal appropriations, I undertook in 1854 the construction of a separate map of each county in the State, excepting the small counties of Suffolk, Dukes and Nantucket, which were included on sheets containing larger adjacent counties. The materials then in existence for such a set of maps included, first, the excellent triangulation made by Mr. Borden some fifteen years before, which had been used as the basis of the official map above mentioned; second, the town surveys ordered by the Legislature and made in 1830 and 1831, from which Mr. Borden compiled the details of his map; and third, more recent town and city maps, including those made by myself, already mentioned. The latter material was to be used, so far as it went, but it constituted a very small portion of what was required.

The old town maps, although drawn to a scale two or three times as large was proposed for the new county maps, were, in many respects, too inaccurate for use. A new survey was accordingly undertaken of all the public highways in the State. A careful estimate of the possibilities of remuneration limited the cost of the survey, including field and office work, to about one dollar and a half per square mile: and, ultimately, this was about the average cost. Hypsometry, as a feature of topographic maps, was at that time only undertaken in a few European Government surveys, made at great expense; and while I fully recognized its value, it was, of course, excluded unless the cost could be defrayed at public expense.*

The scope of the work I had undertaken included the representation of roads, railroads, streams, ponds, marshes, the sea-coast, with its capes, bays, inlets and islands, and of important buildings, including dwellings, churches, school-houses, mills, manufactories, stores, etc. Some hachure sketches of prominent hills, in accordance with the imperfect fashion of the time, indicated the existence of slopes, more or less steep, and served to show where high ground or rough country was to be found, but gave no definite information in regard to actual heights or the true forms of relief. Fortunately, the entire coast-line of the State was shown on the published or manuscript maps of the United States Coast Survey, together with a narrow strip of the adjacent land. So far as it went, this data was all that could be desired. The town maps furnished to the State archives, according to law, in 1831, in advance of Mr. Borden's triangulation, gave representations of town boundaries, roads, streams and ponds. These representations were fairly correct in the groupings of the various features in regard to the relative positions of objects when referred to those immediately adjacent, but owing to the imperfect methods of surveying and want of skill in platting or graphic representation, the map of a town, as a whole, was frequently more or less distorted and deformed. This was readily detected by the discordance between maps of adjacent towns along common boundaries and the impossibility of fitting a number of maps together into a larger continuous map. Since these maps, however, were made by local surveyors, whose knowledge of the general relative positions of roads, streams, water surfaces, etc., would be likely, from the nature of their occupation, to be as thorough as that of any class of people, and, in the main,

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* Before undertaking the work as a private enterprise, I had attempted to procure State legislative action in its behalf, and the subject was referred by the General Court to their Committee on Education. Professor Arnold Guyot, then a resident of Cambridge, and Mr. Simeon Borden kindly interested themselves in the project which I presented, and urged upon the committee the acceptance of my proposal to make a hypsometric survey by tachiometric methods—that is, by the use of graphic triangulation stadia, vertical angles, etc., in connection with traverses of the roads, at a cost of $25,000. These tachiometric methods had then recently been introduced in Europe by M. Porro, a noted Italian topographer. The committee reported a resolve authorizing the survey as proposed (see House Doc. 170, Mass. Leg., 1854), and it had many friends in the Legislature; but the party in power had not the courage to risk being charged with extravagance by their opponents, and the subject was, by a small majority, referred to the next Legislature, where another resolve was reported favoring the work, which was again referred, however, to the succeeding Legislature (see House Doc. 294, Mass. Leg., 1855).

correct, I made use of them to some extent for drainage representation, etc., under a careful system of checks, to be hereafter described.

Having for the basis of the proposed county maps the Coast Survey and Mr. Borden's triangulations, the plan was adopted of traversing all the public highways by course and distance, using the ordinary surveyor's compass for directions, and the revolutions of a wheel for distances. I wish to say a few words here in regard to the comparative usefulness of a wheel for measuring distances along roads. Though less accurate than a chain in the hands of skillful chainmen, it has the merit of economy, since one person with a compass and odometer can do the work of a party of three with a compass and chain. Then, the inaccuracies due to the inequalities of the surface are much less on common roads than, in the absence of tests, would be supposed. In fact, on the ordinary roads of Massachusetts, which usually change their directions in short distances, the error from this cause becomes inappreciable in platting to a scale not larger than $\frac{1}{20000}$, except in long, straight stretches of hilly road. Moreover, there is little or no liability to an accumulation of errors of counting or reading, as with the chain or stadia. For example, if an error were made in reading the dial of the odometer, which usually registers from zero to 1,000 revolutions of the wheel, the error would not accumulate, but would be taken from one adjacent course and added to the other, so that if the change in direction was not great, the resulting error would be slight. In fact, where readings are frequently made in noting features of local topography, buildings, stream crossings, etc., an error of reading is often detected by its incongruity with adjacent readings. In stadia measurements, the distances must be reduced to horizontality, and in ascending or descending, unless the rod is held perpendicular to the slope, another correction becomes necessary, if absolute precision is required. But for traversing across fields, meandering streams, etc., the wheel is unavailable, and, for topographic work, stadia measurements seem preferable to any known method for rapidity and convenience. By the system of traverses adopted, all the highways were surveyed and platted continuously in a network. Each closed circuit of this network not only checked itself, but served to check adjacent circuits. Usually the errors of closure did not exceed one or two per cent. of the distance traversed. An abnormally large gap in the closure of a circuit was checked by the closures of adjacent circuits until its approximate locality was established between two adjacent road junctions, where, by carefully studying the notes, comparing the sketched with the platted angles, the error was, in most cases, detected, being found due to some obviously erroneous reading of the compass or odometer; and finally the few undetected errors, when sufficiently important, were corrected by a resurvey of the defective portion. Upon the final adjustment of the network of roads, the other details of topography, namely, the dwellings, streams, etc., were supplemented. The field notes were first platted upon a scale of $\frac{1}{20000}$, that of the published maps varying from $\frac{1}{10000}$ to $\frac{1}{63360}$.

In order to reduce the work to a geodetic basis, and, as far as possible, to eliminate errors arising from inaccuracy of standard, etc., the traverses were connected with all the primary and secondary stations of

the trigonometric surveys, which could be identified upon the ground, and these stations were marked upon the platted network of roads. Parallels and meridians were then interpolated between the stations for each minute of latitude and longitude, giving the residual seconds their proper value, and dividing the remaining spaces into the proper number of equal parts. A true projection in minutes being made on the publication scale, the original draft was reduced into its proper place, square minute by square minute. The ratio of reduction from the orignal draft to the publication scale agreed very closely, showing the general accuracy of the standard and of the graphic work, the difference being hardly greater than might have been caused by hygrometric changes in the paper.

This brief outline of methods and checks used in the construction of county maps in Massachusetts, now more than twenty-five years old, will give some means of judging whether or not they possessed a value commensurate with their cost in the more exact delineation than had previously been made of horizontal relations between the objects represented. It is quite evident, however, that whatever may have been the character or usefulness of the maps then made, the time has arrived when better methods and more precise results are required. While it is by no means necessary or advisable to entirely discard the method of traversing by which all the minute sinuosities of roads, streams, etc., are rapidly and economically ascertained, this method should be made subsidiary to the more exact processes of triangulation, which should be carried much further into detail than before.

TRIANGULATION.

It is quite unnecessary to discuss before this Society the superiority of triangulation over traverse measurements as a means of determining positions. Starting from a base line measured with the refinements now attainable, the large theodolites constructed for the great geodetic surveys of the world are capable of measuring angles to within a quarter of a second, a degree of precision which renders it possible, as is claimed for the geodetic survey of British India, to determine the ratios between the sides of a network of geodetic triangles to within a theoretic error limit of one two-millionth part of the distance determined. (Address of Gen. J. T. Walker to the Geographical Section of the British Association for the Advancement of Science. See *Van Nostrand's Engineering Magazine*, January, 1886, p. 71.) In the geodetic work of the United States Coast Survey for the Eastern Atlantic States the error limit does not exceed $\frac{1}{288000}$, or less than a foot in fifty miles. (U. S. Coast Survey Report for 1865, p. 195.) For secondary triangulation—that is, the cutting up of the larger geodetic triangles into smaller ones for use in topographic work, etc.—instruments reading to 10″ or even 20″ are considered sufficiently powerful, and with them a precision which would limit the error to one foot in five or ten miles should be easily attainable. Such instruments are not difficult to transport, and there seems to be no advantage in the use of smaller instruments for the preliminary triangulation of a topographic survey.

Graphic Triangulation.—Triangulation, however, in a well-conducted survey by no means ceases with the instrumental and computed work.

It is carried on by graphic processes upon a plane table until it reaches a stage where the triangles are sufficiently small to allow the interpolation of details by stadia measurements, pacing or even eye estimates and sketches. Stadia measurements must be regarded, moreover, as really belonging to the series of triangulation determinations in which the triangles are quite "ill-conditioned," that is, the known base, read off from the rod, is very small compared with the required side, or the distance between the reading instrument and the rod. The solution of these triangles by simple inspection sustains a relation to computation work similar to that of the slide rule. Such measurements can only be used to advantage for comparatively short distances, one thousand feet being about the maximum distance from the instrument at which distances can be read with sufficient precision.

Eye Estimates.—Eye estimates, even, are a species of triangulation They are probably made by an unconscious comparison of sensations which accompany an adjustment of the focal length of the crystalline lens supplemented by a stereoscopic adjustment of the optical axes of the two eyes.

They are aided, where circumstances will permit, by comparisons of spaces occupied upon the retina by the images of fences, buildings, trees, animals and other objects of known size at different distances. Another aid to eye estimates is found in "aërial perspective," as it is termed by artists, or a certain haziness caused by minute opaque particles in the air, tinging objects with a purplish color, gradually changing to a blue approaching that of the sky as the distance increases. This change of color and the gradual loss of distinctness and merging of objects into each other afford a rough measure of relative distances.*

The bases of the triangles in the cases of eye adjustment are, first, the diameter of the crystalline lens at its opening, and, second, where the stereoscopic adjustment is made, the space between the two eyes. It must be remembered that there is no cotemporaneous scale of comparison for eye estimates. They are only obtained by a comparison of present sensations with former experiences, in which distances were estimated and verified by reliable measurements. It may be questioned, even, whether eye adjustments can practically be made in absolute conformity to the distance, and whether attempted adjustments are not affected by the personal condition of rest, fatigue, excitement, etc. It must be admitted, however, that in this, as in other uses of the senses, continual practice will be likely to lead to a remarkable degree of skill. Some of the topographers of the Geological Survey, for example, have attained an eminent degree of proficiency in eye estimation, and are able to sketch upon their field sheets the topography within a radius of several miles around each station occupied, and sketches so made are said to fit each other fairly well where they join or overlap. Where the limit of time and cost renders it necessary for each topographer to cover some thousands of square miles in a season with a sketch map of previously

* In the discussion which followed the reading of the paper, Mr. Fred. Brooks remarked that the distances of objects seen across water were deceptive, owing to the absence of objects of comparison, and that an unusual clearness of the air in mountain regions caused distant objects to appear nearer than they really were.

unexplored country, which shall give a general view of its salient features until a more careful survey is available, the use of "sketching stations" and eye estimates over such extended areas may be unavoidable, but it is quite evident that for State surveys such estimates must be limited to short distances and for the location of comparatively unimportant objects.

When at length the triangulation processes, including estimates of distances, cease, the topographer completes his work by sketching in from point to point the irregular curves which express the contours of the surface. Here his success depends upon a sense of form and proportion comparable with that of the landscape or portrait painter.

Amount of Preliminary Instrumental Triangulation Needed.—We are now confronted with the question, how much instrumental and computed triangulation should precede the final graphic or plane table work in the survey of a comparatively well settled State, like the New England States, New York, New Jersey, Pennsylvania, etc.? This will depend in part upon the scale of the map to be constructed, since the scale will govern the area to be included in the field sheets, which may conveniently be used. It is considered indispensable that each plane table sheet shall contain at least three precisely determined points, laid down upon it in advance of its use in the field, two of them serving for a base, and the third for verification. These three points should be spread apart in an advantageous manner, be intervisible and command views of other controlling points coming within the limits of the sheet and suitable for occupation. While in skillful hands and with a good plane table, the accuracy with which triangulation may be performed is commensurate with the scale of the work, it is also true that many advantages would accrue from having numerous well chosen points located upon the sheet with the precision of numerical computation, since it is evident that the topographer could then proceed with certainty and dispatch to fill in the spaces between the smaller triangles thus formed; but the cost of graphic triangulation being somewhat less than that of the computed work, the question where the latter shall cease and the graphic work commence becomes one of relative value and cost. The cost of the field work for determining stations more than two or three miles apart is not greatly different in the two methods, but the additional cost of computation swells the expense of the instrumental method. Some of the principal officers of the United States Coast and Geodetic Survey hold to the opinion that at least one computed position should be given in every square mile of area for the best results in plane table work. Other skillful topographers are satisfied with stations three or four miles distant from each other. If, as in Massachusetts, the monuments marking angles in state, county and town boundaries are to be determined by computed triangulation, these determinations, with the auxiliary stations needed to reach them, will furnish points averaging less than three miles between adjacent stations and will constitute a sufficient amount of secondary triangulation to precede plane table work and enable the topographer to carry it on with rapidity and precision.

Utility of a Triangulation Basis in Civil Engineering.—Mr. Borden, in making his careful triangulation of Massachusetts, considered that one

of its most valuable uses would be to serve as a basis for the work of civil engineers and land surveyors, who would thereby attain a high degree of precision in extended surveys, as well as a means of connecting independent surveys together with almost absolute certainty. Accordingly, for the use of surveyors, etc., he not only computed the geodetic coördinates, or latitudes and longitudes, but gave rectangular coördinates from convenient reference points. It is obvious that these data are more simple and better adapted for the use of civil engineers, while over limited areas their precision is not sensibly impaired by the curvature of the earth's surface. But his primary stations were too far apart to be conveniently used in this way, and the time had not arrived when the advantage of coördinate determinations would be sufficiently appreciated by civil engineers who had been brought up in less reliable methods. There were a few exceptions, however, including ex-President Doane of this Society, and some of his pupils, who systematically referred their surveys to the coördinate axis used by Borden in this vicinity, namely, the meridian of the State-House dome and a line at right angles to it. Some of the extended maps of surveys for the water supply of Boston are similarly referred. At the present time many town and city engineers, including several members of this Society, have expressed their intention to connect their work in a general coördination as soon as the secondary triangulation, which is expected as a preliminary to the present topographical survey of the State, shall bring stations within their convenient reach.

Under prevalent methods of surveying, great uncertainty often arises in attempting to re-locate lines where monuments have been lost or displaced; but, if carefully connected with an extended triangulation, the uncertainty disappears, and the work is effectually removed from the arena of dispute and litigation by the certainty with which the controlling positions may be restored from the triangulation stations. In those cities and towns where cadastral surveys are to be undertaken, the advantage of such a basis for the work is obvious. In fact, a continuous survey, for any purpose, extending over a considerable area, can best be rendered consistent with itself and its surroundings by basing it upon an extended triangulation, and bringing it into a general system of coördinates.

There is another consideration which should not be overlooked in discussing the amount of preliminary triangulation needed in State surveys. In many populous districts the questions of water supply and sewerage are pressing with great force upon public attention. Surveys are likely to be needed for the investigations called for, involving a higher degree of precision than the limit of cost fixed for the State survey would cover. A true economy would seem to require that as much as possible of the work done should be available for such future exigencies. An exact instrumental triangulation would cost but little more tham imperfect graphic work, whose occupied stations would be unavailable for any subsequent surveys, while the computed positions would serve as reliable reference points for all future work.

On the whole it would seem that a wise view was taken of the proper functions of the General Government when authority was given to the

Coast and Geodetic Survey by Congress to furnish State governments with secondary triangulation brought to a sufficient degree of minuteness to meet the requirements of topographic work. With adequate appropriations to sustain the authority thus given, there ought to be no difficulty in solving the question as to where secondary triangulation should end and graphic work commence. A proper coördination between the geodosists and the topographers in this respect would diminish the labor and cost of topography while augmenting the precision of its results.

Subsidiary Traverse Work.—A skillful topographer, accustomed to the constant use of the plane table, will not readily admit the need of subsidiary work in which field notes and subsequent platting are required Upon scales as large as $\frac{1}{10000}$ or $\frac{1}{15000}$ the topography may all be drawn directly upon the plane table. Where streams and roads in wooded regions are to be shown, with all their sinuosities, traversing is resorted to, care being taken to connect the traverse lines as frequently as possible with the triangulation points. By orienting the plane table at each angle and measuring distances with the chain or stadium rod, traverses may be made without resorting to field notes. When, however, the scale is diminished to $\frac{1}{20000}$ or smaller, and a more rapid progress over a given area undertaken, a considerable saving of time is effected by resorting to extra field notes for roads and streams, using a light instrument for angle measurements. The field notes might be dispensed with, perhaps, by using a light and portable supplementary plane table having, however, sufficient stability to permit a few observations at each point occupied without disturbing the orientation, which might be maintained by using a declinometer or magnetic needle. In this way all objects visible from the line of traverse could be rapidly laid down and the drawing compared on the ground with the objects represented, an advantage over platting from notes that topographers will appreciate. The light plane tables used for mountain work by some of the topographers of the United States Geological Survey seem adequate for this subsidiary traversing, which might be carried on by the younger members of a party. They will usually find more satisfaction in adopting a larger scale than that of the large plane table sheet, to which their work can easily be reduced by proportional divides when ready for transfer.

HYPSOMETRY

Besides attaining a general coördination of results in two dimensions with a greater degree of accuracy than most commercial maps, constructed from traverse surveys, exhibit in the horizontal representation of surfaces, government surveys are now expected to take the third dimension into account by presenting *vertical relations.* These are best expressed upon the maps by a series of lines corresponding to the intersections of certain imaginary level surfaces with the surface of the country represented. The first or lowest of these surfaces, as adopted by the United State Coast and Geodetic Survey and the United States Geological Survey is that of the ocean supposed to be at rest in the absence of tidal influence. The intersection of the mean sea level with the land surface corresponds to the coast line at mean half tide. Imagine the ocean to be raised twenty feet higher, still undisturbed by tides,

and draw the new coast line upon the map. Let the ocean be again and again raised, each time twenty feet higher than the last. The successive coast lines thus formed and drawn upon the map would represent lines having the same height throughout, to which the name "contour lines" has been applied in hypsometry. An objection to this name is that it does not convey the idea of equal height, and might be applied with equal propriety to other than horizontal outlines, for example, to a vertical profile, or to the outcrop of an inclined strata, etc. A word given in Greek lexicons, namely, isohupes (ἰσοϋψής), a compound word signifying equally high, would more nearly express the meaning intended. Other intervals between the successive isohupes might be adopted to suit the circumstances of scale, steepness of slopes, etc. The topographers of the United States Geological Survey show isohupes upon their territorial maps with differences of level from one hundred to two hundred and fifty feet. Upon their surveys of Massachusetts and New Jersey the interval is twenty feet, and the same interval prevails in the topographic work of the United States Coast and Geodetic Survey.

Leveling.—The most accurate known method of ascertaining differences of height is by means of the spirit level, but to carry this method into all the details of a State survey would be far too laborious and expensive, especially where the changes of level are frequent and considable in amount. Its use may generally be limited to the running of a series of check lines across the surveyed area, and establishing thereby a system of bench marks to which levels determined in other ways may be referred.

Bench Marks and Reference Levels.—As in determining the horizontal relations of objects, a preliminary triangulation is necessary to fix a convenient number of reference points, so in a hypsometric survey, equal or greater care should be exercised to provide in advance reliable bench marks to which the heights of objects may be confidently referred. A failure to do this will sooner or later involve the work in confusion. In geodetic operations it is usual to determine the relative heights of all the triangulation stations, by measuring vertical angles or zenith distances from one to another. A fair degree of precision is attainable in this way, the most important vitiating factor being the unequal refraction of the visual ray while passing through air in variable degrees of density. In Massachusetts this method was pursued by Mr. Borden as well as by the United States Coast and Geodetic Survey, with nearly coincident results, where the stations were identical.

Precision in Hypsometry.—The practical uses to which hypsometric information is applied require even greater precision in height determination than in the horizontal relations of topography. An error in the designated height of a stream at any particular point would be more important than the horizontal displacement of the point to a considerably greater extent. Questions of water-power, for example, would require for satisfactory solution a pretty exact knowledge of the amount of fall in the stream. Indeed, the horizontal displacements of incorrect isohupes would, in general, be far greater in amount than the vertical errors involved. It is seldom in nature that slopes are found so steep as

forty-five degrees, or a unit of base to one of height. A slope with a base of six horizontal to one vertical on a road would be considered steep. Here the horizontal displacement would be six times the vertical error, and this ratio increases rapidly as the slope approaches to a level. Hence, the necessity appears for an increased precision in height determinations where the surface of the country is made up of gentle undulations. It is also evident that the instruments used for determining differences of level across a State should be capable of a high degree of precision. Since the alidades usually accompanying plane tables are supplied with vertical circles only reliable for comparatively short distances, the necessity for frequent well-determined bench marks presents an additional reason for carrying on the secondary triangulation with the theodolite, including height determination by vertical angles in advance of the graphic work, as far as the expense limit will permit.

Engineering works already constructed in the older States, more especially the railroads and canals, were usually preceded by leveling surveys, made with much care. From these surveys profiles showing the inequalities of the surface were drawn with the heights marked in feet above some reference or datum level. Upon the profile of a railroad, its gradients and the amount of cutting and filling along the line were established. On the completion of the road its profile, if well made, would accordingly show the exact rate and amount of its successive rises and falls, and the absolute height of any point above the datum level.

The simplicity of the work, and the obvious necessity for a reasonable degree of precision to avoid ultimate confusion, would seem to warrant the expectation that railroad profiles might be used to great advantage in hypsometry. But, on comparing the profile of intersecting roads, many discrepancies are found, arising partly from uncertainties as to the datum level adopted, and partly from a want of care and skill in the preliminary work.

Fortunately, leveling surveys can usually be carried with much greater facility along the roadbeds of railroads already constructed, than over the uneven original surfaces. Much perplexing uncertainty would be avoided, and the work of a topographic survey greatly facilitated, by the comparatively inexpensive expedient of carrying preliminary lines of level across the State, and across each other along the main lines of constructed railroads. In this way they would check each other, and afford the means of correcting and adjusting all the connecting railroad profiles to a common datum level. These profiles should be connected with the trigonometrically determined points at convenient places, in order to unite all the data into one reliable system of reference heights.

Where, as in many parts of New England, the water power of rivers is fully or in great part utilized, preliminary connections should be made with the surfaces of mill ponds or the crests of dams along manufacturing streams. Here the owners of mills have generally taken measures to ascertain the exact relative height of their own dams and of those above and below them, the value of their water privileges depending upon units of differences of level. In Massachusetts accurate profiles are in existence of such rivers as the Connecticut, Merrimac, Charles,

Sudbury, Nashua, Blackstone, Housatonic and others. Surveys for the water supply of cities and towns generally include carefully executed levels of great hypsometric value in the regions thus investigated.

Of course, for connecting all these levels with the mean level of the sea, access must be had to the sea coast, where, to obtain the mean level, observations are needed of high and low water. For great precision a long series of observations is requisite. These, however, have been made, and bench marks established in many of the ports and harbors along the coast, by the United States Coast and Geodetic Survey.

Plane Table Hypsometry.—Having the preliminary data for location and heights carefully established, the topographer is prepared to take the field with his table, secure from the confusion which would attend an inadequate and uncertain determination of positions and heights. The determination of heights in plane table work is almost entirely by means of vertical angles, the alidade of the instrument being provided, for that purpose, with a small vertical circle. On account of the greater precision required, heights are not, like horizontal determinations, obtained graphically. The angles are instrumentally measured, and the distances being scaled from the map, the differences of level are computed or taken from tables. A more convenient method than either might be found, perhaps, in the use of a specially designed slide rule. Without going into the details of plane table methods, it is sufficient to say that the height of each plane table station having been determined, either before occupation, if located by intersection from other stations, or immediately after, if located by resection or by the three point method, is used in turn to fix the heights of all points determined more or less directly from the new station. If the preliminary work has been properly done, and the topographer is skillful in selecting his points of occupation, he will always have several determined points in view from which he can find with certainty both his horizontal position and its height. Spires, cupolas, gables, chimneys, flag-staffs, remarkable trees, rocks, etc., afford good reference points, and their heights at the top, or at some conspicuous point like a weather vane, etc., having been determined, they also form good bench marks. As fast as positions are located upon the plane table sheets, their heights should be marked and the adjacent isohupes interpolated between them. *This should invariably be done in the field*, not left for future office work, which at best is likely to fail in the critical places where the characteristic expressions are to be brought out. Attempts to make character sketches by conjectural contours of indefinite height are sure to fail if not based upon exact truth. True isohupes, with rare exceptions, are themselves the best character delineators. Auxiliary lines with smaller intervals may be interpolated between the isohupes of regular intervals, where some peculiarity of feature would fail to be otherwise expressed, and a skillful topographer sometimes takes the liberty of slightly displacing an isohupe from its theoretical position to secure an expression of nature which the true isohupe would fail to bring out, owing to a certain neutrality due to its arbitrary height, somewhat above or below that of the characteristic feature.

Comparative Utility of the Plane Table.—Enough has been said, per-

haps, to show the advantages of the graphic method of representing topographic details when compared with the use of field notes and office platting. A topographer who has become familiar with the use of the plane table cannot easily be persuaded to adopt other methods for his special work. Even under unfavorable circumstances, for example, where the geodetic and secondary triangulation points are widely scattered, and extensive vistas are precluded by numerous wooded areas, he will carry in from outside bases a chain of graphic triangulation, extending it between the wooded patches until he finds a check by coming again to previously determined bases. The accuracy of such work is far greater than can be expected from traversing between the widely separated, non-graphic triangulation stations, especially where directions are referred only to the magnetic needle. Of course, well executed previous surveys may sometimes be incorporated into the work with advantage; as, for example, where accurate maps of the compact portions of cities and populous towns are found. These can usually be reduced to the required scale, and after laying down a few of the principal streets by the graphic methods, the remaining network of streets, etc., can be fitted into its proper place. Much assistance may be derived, in locating railroad lines, especially where the curvature is complicated, by platting the engineer's alignment to the scale of the plane table sheet, and fitting it between points graphically determined. The advantages of the graphic method, especially in the projection of isohupes, would obviously be lost, however, if any considerable part of the work were left to be completed, after leaving the ground, by platting field notes or sketching from memory. Besides the loss of time, there is the large element of uncertainty which usually attends the deciphering of sketch notes after they have become "cold" by lapse of time.

As the success of the portrait painter is measured by his skill in reproducing not only the more striking and familiar features of his subject, but a certain subt'e, undefinable expression of individual character, so the topographer is a true artist who brings out upon his map not only the salient contours of the country, but the less apparent though real markings which reveal to experienced eyes the conflicts of the past between the great sculpturing forces of nature and the rugged resistances which have opposed them, the effective touches in either work of art being applied *in the presence of the subject portrayed*, with a true artistic sense of form and proportion.

THE STRENGTH OF SOME LOCAL BUILDING STONE.

By Prof. John Eisenmann, Member of the Civil Engineers' Club of Cleveland.

[Read October 13, 1885.]

The paper which I present to you this evening is practically the report made by 1885's graduating class of the Case School of Applied Science. In giving the instructions to the class I thought it advisable to employ the proportions given, and thereby approach as nearly as possible to the Kensington recommendations of testing materials in prismatic forms,

whose heights are about one and a half times the base. You are probably aware that Gen. Gilmore's tests were made with two-inch cubes between steel, wood, lead and leather plates The tendency of to-day is to test material at nearly the natural size, or at least to employ dimensions which are proportional to those in use on constructions. Speaking generally, the results of recent tests of building material, made on larger specimens, have shown that the resistance does not increase with the ratio of the unit found from experiments upon smaller specimens; and in many instances the large factor of safety employed is the only salvation of the structures.

Cleveland and vicinity have some of the most valuable sandstone quarries found in this country, in fact, our reputation as a stone market is national. New quarries are constantly being opened and their product put upon the market. The question then arises, what is the durability and strength of thatmaterial? The instructions to the class were to send their circulars of invitation to the newer quarries, and to reserve a few for the older for the sake of comparison with former tests. About one-half of the circulars sent out were responded to by sending samples, but two or three of these came too late for complete investigation, hence are omitted from the report.

It is also a matter of regret that the time of the class was too limited to push the investigation further, so as to include the tests for abrasion, fire and frost. However, suffice it to say, their work is but a nucleus of that which we expect to accomplish in the future, when a more extended series of tests will be made. I will give you their report verbatim, as it fully explains itself, and it may be given whatever weight you think it deserves. I will say for it that a more conscientious set of tests is rarely made, the young men working with a true spirit of research, having had every facility afforded by the chemical and physical laboratories of the school placed at their disposal. And by the courtesy of the management of the Otis Steel Works, they had the full use of a large Olsen testing machine. The work was performed either under my personal supervision or that of Assistant Prof. James Ritchie.

CLEVELAND, O., June 15, 1885.

To J. Eisenmann, C. E.,

SIR: We hereby respectfully submit the results of our investigation of the qualities of certain sandstones used in this vicinity for engineering and building purposes.

The work was divided into three parts:

1st. Chemical Analysis.

2d. Specific Gravity and Ratio of Absorption.

3d. Resistance to Crushing and Transverse Strain.

Invitations were sent to stone companies and owners of quarries to prepare specimens after the following specifications:

Three sets of specimens should be selected from different parts of each quarry, the specimens composing each set being chosen from immediately adjacent portions of the same stone,

A set should be composed of:

1st. Two specimens for resistance to compression, 3 in. × 3 in. × 4 in. one to have length running with the bed and the other across it.

2d. One specimen for resistance to transverse strain, 3 in. × 4 in. × 14 in., to have length running with the bed.

3d. One piece of rough stone for analysis determination of specific gravity and ratio of absorption.

Note.—Specimens for compression and transverse strain should have their surfaces rubbed true and smooth, and be of uniform cross section throughout. They should have their corners perfect and square, and be marked with the number of the set and direction of bed.

These invitations were responded to by W. H. Caine, three sets of specimens, Newburgh, Ohio; McDermott & Berea Stone Company, Berea, O.; Claflin Paving Company, one set Medina stone, Albion, N. Y.; C. W. McCormick & Co., three sets of specimens, Twinsburgh, O.; Ohio Building Stone Company, four sets of specimens, Amherst, O.

The chemical analyses were made in duplicate and the mean taken as final, providing they agreed within one-tenth of one per cent.

The ratio of absorption and specific gravity were found as follows:

1st. The sample was weighed in the air.

2d. The sample was immersed in pure water and the air exhausted from it under the receiver of an air-pump, then weighed again in the air after removing all superfluous water from surface.

3d. The sample was then weighed again while suspended in pure water, with its voids still filled.

Corrections were made for any disintegration in saturating and for the weight of the thread in suspending from the scale pans. The ratio of absorption of a stone is the ratio of the maximum volume of water that can be absorbed by it to the volume of the stone; or the ratio of the difference between the second and third weighings to the difference between the first and second. The specific gravity of a stone is the ratio of its weight in air to that of a corresponding volume of water; or the ratio of the first weighing to the difference between the second and third.

The cut samples were tested for resistance to crushing and transverse strain between lead plates in the Olsen testing machine of the Otis Iron and Steel Works, who had kindly tendered us its use.

In the accompanying tables will be found the entire results.

In all stones analyzed, the foreign substances in the cementing material existed as oxides, carbonates or silicates. When iron is present as ferrous carbonate ($FeCO_3$) it is injurious, since it tends to oxidize, forming rust streaks, and when in considerable quantity will disintegrate the stone. Calcium and magnesium carbonates ($CaCO_3$ and $Mg.CO_3$) are also injurious to the stone when exposed to the action of the weather, especially at the seashore and in large manufacturing cities, where there are more or less acid vapors in the atmosphere. Alkalies, when present, will in time be washed out and the stone injured by an amount depending on the quantity of cementing material thus removed.

The specimens were chosen of such shape and dimensions as could be easily dressed without injury. Although in most cases the samples were carefully cut, we found the surfaces of some not quite parallel, thus causing an uneven strain.

For transverse strain the distance between supports was ten inches and

Name, Chemical Analysis, Etc.		No. of specimen	Dimensions of cross-sections.	Direction of bed	Crushing strain	Crushing strain per sq. in.	Remarks
					Crushing.		
		1	1 7/8 × 2	2 × 4	23,010	6,136	Sudden fracture.
Name—Newburgh		2	2 × 2	2 × 4	16,450	4,112	Bearing not true; at the centre.
		3	1 7/8 × 1 7/8	2 × 4	15,010	4,264	
		4	1 7/8 × 2	2 × 2	35,110	9,450	
Chemical analysis	Per cent.	5	1 7/8 × 1 7/8	2 × 2	30,600	8,693	
Silica (SiO_2)	86.19	6	1 7/8 × 2	2 × 2	29,450	7,853	Sudden fracture.
Iron carbonate ($FeCO_3$)	6.73						
Calcium carbonate ($CaCO_3$)	1.75				Transverse strain		
Alumina (Al_2O_3)	4.04		l b h		Breaking strain		
Alkali (Na_2O)	0.51	1	10 3 2	3 × 10	1,480	1,850	Sudden fracture.
Water (H_2O)	0.61	2	10 3 2	3 × 10	1,480	1,850	Sudden fracture.
		3	10 2 3	3 × 10	2,100	1,750	Fractured diagonally.
	94.83						
Specific gravity	2.31						
Ratio of absorption	0.09						
Color—Drab.							
					Crushing.		
Name—Berea		1	2 7/8 × 2 7/8	3 × 4	32,850	3,974	Crushed on ends first.
Chemical analysis.	Per cent.	2	2 7/8 × 3	3 × 4	32,150	3,729	Fracture in one corner.
Silica (SiO_2)	96.90	3	2 7/8 × 2 7/8	3 × 4	29,320	3,547	
Iron carbonate ($FeCO_3$)	1.98	4	3 × 3	3 × 3	49,820	5,536	
Calcium carbonate ($CaCO_3$)	0.25	5	2 7/8 × 3	3 × 3	38,100	4,418	Fracture on one side.
Alkali (Na_2O)	0.55	6	2 7/8 × 3	3 × 3	5,300	6,145	Fracture sudden.
Water (H_2O)	0.30						
	99.98				Transverse strain		
			l b h		Breaking strain.	R	
Specific gravity	2.15	1	10 4 3	4 × 10	1,480	635	
Ratio of absorption	0.18	2	10 4 3	4 × 10	1,060	440	
Color—Drab.		3	10 3 4	4 × 10	2,000	630	
					Crushing.		
Name—Medina		1	3 × 3	3 × 4	83,050	9,228	Started to crack at 75,000.
Chemical analysis.	Per cent	2	3 × 3	3 × 3	61,620	6,846	
Silica (SiO_2)	97.46						
Peroxide iron (Fe_2O_3)	0.84				Transverse strain.		
Calcium carbonate ($CaCO_3$)	0.31		l b h		Breaking strain.	R	
Alkali (Na_2O)	0.90	1	10 3 4	4 × 10	4,800	2,000	Sudden fracture.
Water (H_2O)	0.47						
	100.01						All specimens well dressed.
Specific gravity	2.42						
Ratio of absorption	0.05						
Color—Light red.							
					Crushing.		
Name—Twinsburgh		1	3 × 3	3 × 4	51,080	6,010	
Chemical anlysis	Per cent.	2	3 × 3	3 × 4	40,680	4,520	
Silica (SiO_2)	94.00	3	3 × 3	3 × 4	34,840	3,871	
Peroxide iron (Fe_2O_3)	5.06	4	3 × 3	3 × 3	37,560	4,173	
Water (H_2O)	0.93	5	3 × 3	3 × 3	32,110	3,568	
		6	3 × 2 7/8	3 × 3	40,700	4,719	Crushed at corners.
	99.99				Transverse strain.		
Specific gravity	2.19		l b h		Breaking strain.	R	
Ratio of absorption	0.18	1	10 3 4	3 × 10	1,920	600	
Color—Red.		2	10 3 4	3 × 10	1,600	500	Flaw—not set even.
		3	10 4 3	3 × 10	1,340	560	
							All specimens well dressed.
					Crushing.		
Name—Amherst							
Chemical analysis.	Per cent.	1	3 × 3	3 × 4	33,200	3,690	Broke on corner.
Silica (SiO_2)	94.21	2	3 × 3	3 × 4	49,800	5,537	Broke on edge.
Iron carbonate ($FeCO_3$)	2.30	3	3 × 3	3 × 4	21,450	2,380	Not a fair test.
Calcium carbonate ($CaCO_3$)	1.86	4	3 × 3	3 × 3	47,960	5,330	
Magnesia carb. ($MgCO_3$)	0.97	5	3 × 3	3 × 3	37,850	4,206	Broke on corner.
Water (H_2O)	0.70	6	3 × 3	3 × 3	49,690	5,521	Sudden fracture.
					Transverse strain.		
	100.04						
Specific gravity	2.11		l b h		Breaking strain.	R	
Ratio of absorption	0.19	1	10 4 3	4 × 10	1,520	633	
Color—Drab.		2	10 4 3	4 × 10	1,950	812	
		3	10 3 4	4 × 10	2,720	1,350	Sudden fracture.
							All specimens well dressed.
							From Nickel Plate Quarry.
					Crushing.		
Name—Amherst.		1	3 × 3	3 × 4	45,000	5,000	
Chemical analysis.	Per cent.	2	3 × 3	3 × 3	37,910	4,210	
Silica (SiO_2)	96.90						
Iron carbonate ($FeCO_3$)	1.15				Transverse strain.		
Calcium carbonate ($CaCO_3$)	0.80		l b h		Breaking strain.	R	
Water (H_2O)	1.05	1	10 4 3	4 × 10	1,560	650	All specimens well dressed.
							From Nickel Plate Quarry.
	99.90						
Specific gravity	2.73						
Ratio of absorption	0.18						
Color—Buff.							

5,531

the force was applied midway between them. The specimen for this test in the third set was tested on its edge as can be seen from the table.

The quantity R is a constant derived from the formula $R = \frac{3}{2}\frac{Pl}{bh^2}$ in which

P is the breaking strain,
l " distance between supports,
h " height of specimen,
b " breadth of specimen.

Having obtained R for the various stones it can be substituted in the following formulæ, which give the breaking weights for the ordinary methods of loading.

For concentrated load $P = \frac{2}{3}\frac{Rbh^2}{l}$ in which P is the breaking weight applied midway between supports; l, the distance between supports, and b and h, the breadth and height respectively of the stone.

For uniform load $\bar{P}\,l = \frac{4}{3}\frac{Rbh^2}{l}$ in which $\bar{P}$ is the load per unit of length and the other notation same as above.

With the exception of the Newburgh and Amherst stones, the former having been quarried two months and the latter two or three days, the specimens were between one and two weeks old.

Upon a comparison of these tests with those of Gen. Q. A. Gillmore, we find that his results are higher: but this may be partially accounted for by the fact that his specimens were smaller and more thoroughly seasoned.

L. F. Brewster.
Daniel R. Warmington.
F. H. Kindl.
J. Wand.

[N. B.—The sulphur test was applied, but no traces of sulphur were found in any of the specimens tabulated above.—J. E.]

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 20, 1886:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:40 P. M., Mr. C. W. Folsom in the chair; forty-three Members and ten visitors present.

The record of the last meeting was read and approved.

The amendment to Section 2 of the By-Laws, proposed in writing at the last regular meeting, was adopted. Affirmative, twenty-three; negative, six.

The Secretary announced that through the efforts of Mr. F. P. Stearns an exchange of publications had been provided for between the Institution of Civil Engineers of Great Britain and this Society, and that twenty-three volumes of the minutes of the proceedings of the Institution of Civil Engineers had been received.

On motion it was voted: That the Secretary be instructed to acknowledge the receipt of the minutes of the proceedings of the Institution of Civil Engineers, and the publications of this Society be sent in exchange.

The Secretary read a letter from Mr. Clemens Herschel in answer to a vote of this Society, on the matter of National Engineering.

On motion of Mr. Fred. Brooks, it was voted: That the Society proceed to its literary exercises.

Mr. George T. Sampson read a paper on Frogs and Switches.

Mr. Elliot C. Clarke addressed the Society on Investigations made by the Massachusetts Drainage Commission.

Messrs. E. L. Cortheil, H. C. Keith and W. H. Stearns were elected members of this Society.

Letters were read by the Secretary from Mr. E. L. Corthell concerning the Cleveland Convention. On motion, it was voted: That these communications be referred to the Committee on National Engineering.

Notices were read of the forty-fourth meeting of the American Institute of Mining Engineers, the sixth annual meeting of the County Surveyors and Civil Engineers of Indiana, the seventh annual meeting of the Ohio Society of Surveyors and Civil Engineers, the second annual meeting of the Connecticut Civil Engineers' and Surveyors' Association.

[*Adjourned.*] H. L. EATON, Secretary.

JANUARY 27, 1886:—A special meeting of the Boston Society of Civil Engineers was held and called to order at 7:30 P. M., President George L. Vose in the chair; forty Members, nine visitors present.

Mr. Clemens Herschel addressed the Society on the work done at the Holyoke Dam in the year 1885.

Mr. Herschel exhibited a model showing the original construction of the dam, the addition made in later years to strengthen it, and the work done in 1885. Models of the cribs used in making repairs on the dam were also exhibited.

A clear and concise historical account of the formation of the company and the location of the dam was given, with explanation of the dangers which threatened the destruction of the dam in later years, and the plan adopted to prevent it, the condition of the dam in 1885, and the work done in 1885 to preserve and in a measure to replace it by filling its voids with gravel.

At the close Mr. Herschel presented the Society a set of three photographs illustrating the work done in 1885.

[*Adjourned.*] H. L. EATON, Secretary.

FEBRUARY 10, 1886: A special meeting of the Boston Society of Civil Engineers was held jointly with the New England Railway Club, and called to order at 7:10 P. M., Mr. J. W. Marden, President of the New England Railway Club, in the chair, and twenty-nine Members of the Society present.

The following question was proposed for discussion: "The Relation of the Road-bed to the Rolling Stock, and the Methods, Forms and Materials best adapted for Use in their Construction."

The discussion was confined mainly to the gauge of wheels, the shape of wheel flange, the cause of sharp flanges, the difficulty in introducing a uniform standard wheel gauge, the different standards in use by New England railroads, the construction of car truck, the widening of gauge on curves, and the form of cross-section of rail.

This Society was represented in this discussion by Messrs. Bissell, Hardy, Bidwell, Simpson, Doane, Oliver and Folsom.

The discussion proved to be very interesting, and at a late hour it was voted: That this subject be continued for future discussion, the time and place to be arranged by the Presidents of both Societies. H. L. EATON, Secretary.

[*Adjourned.*]

[For a report of this meeting in detail, see American Journal of Railway Appliances Vol. VI., No. 7.]

ENGINEERS' CLUB OF ST. LOUIS.

FEBRUARY 17, 1886:—Club met at 8:15 P.M at Mercantile Library, President McMath in the chair, and twenty-two Members and two visitors present.

Minutes of last meeting were read and approved.

The Executive Committee reported the adoption of the following rule: "Members in arrears whose JOURNAL has been stopped will be notified of the same within thirty days, and informed that they are liable to be reported to the club and published in the proceedings as delinquent."

The club decided to tender Colonel Henry Flad a complimentary lunch in honor of his election as President of the American Society of Civil Engineers.

Mr. Holman moved that a committee of three be appointed to consider and report at next meeting upon the probable cost and programme for the lunch. The motion was carried, and Messrs. Holman, R. Moore and Ockerson were appointed as that committee.

Mr. S. Bent Russell read a paper on "The Efficiency of a Pipe System for Furnishing Water to Fire Engines."

A general discussion followed.

[*Adjourned.*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

FEBRUARY 2, 1886:—The 221st meeting was held on Tuesday, February 2, 1886, at 7:30 P. M., President Wright in the chair.

The minutes of the preceding meeting were read and approved.

Applications to be admitted as Members were received from Mr. Charles L. Strobel, consulting engineer Keystone Bridge Co., residing in Chicago, indorsed by Messrs. Gottlieb, Cregier and Artingstall; and from Mr. George Frederick Samuel, assistant engineer, town of Lake View, indorsed by Messrs. Cole, Alvord and Wright.

Mr. William S. Grant-Synn was elected a Member.

Mr. Arthur M. Kinsman was transferred from the grade of Associate to that of Member.

The thanks of the Society were voted to the Ohio Society of Surveyors and Civil Engineers for an invitation to attend its seventh annual meeting at Columbus, January 12, 13, 14, 15; and to the American Institute of Mining Engineers to attend the forty-fourth meeting of the Institute, to be held at Pittsburgh, February 16, etc.

The Secretary presented from the Trustees the following

REPORT.

The Trustees have, in accordance with the request made at the last meeting, taken into consideration the general interests of the Society, and are of opinion that some changes in the conduct of its affairs may be desirable. At the present time, however, the greatest need is a large increase in the number of Members. If the membership can be doubled the value and efficiency of the Society will be increased in a much greater proportion. It would seem, therefore, that the firs effort should be in this direction, and that it is practicable for each of the present Members to bring into the Society at least one new Member. Believing that the best way to accomplish this is to make the pecuniary burden of membership as light as possible, it is hereby recommended that the amounts for entrance fee and annual dues be reduced.

A full discussion of the report was had, after which Mr. Artingstall proposed the following amendments to the By-Laws:

1. No entrance fee shall be collected from new Members after January 1, 1886.

2. Members residing in Cook County, Illinois, shall pay dues at the rate of six dollars per year; all other Members of every grade shall pay at the rate of five dollars.

A resolution was adopted that the Members present favored the proposed amendment.

Mr. Williams, Manager, presented a bill from the Association of Engineering Societies for the second installment of the assessment for the JOURNAL, ordered August 31, 1885, amounting to $106, which was ordered paid.

A paper was read by Mr. Zellweger, "The Cremation of Garbage."

The Secretary read a communication from Mr. Palmer calling attention to the convention of the American Society of Mechanical Engineers, to be held in Chicago, May 25 to 28, and suggesting that the Society should take some action in relation to this.

It was voted that the President appoint a committee to report on this matter. Messrs. Palmer, Cregier and Gottlieb were appointed as this Committee.

A resolution was adopted that the portrait of President Wright be added to the collection of portraits of former Presidents, and requesting ex-President Williams to sit for the portrait previously voted by the Society, but not as yet ordered, on account of the want of funds to pay for it.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

MARCH 2, 1886 :—The 222d meeting was held at 7:30 P. M., President Wright in the chair.

Messrs. C. L. Strobel and G. F. Samuel were elected Members.

The Secretary announced the receipt of photograph likenesses from Messrs. D. J. Miller and A. Comstock.

Mr. Palmer, for the Committee on Entertainment of the American Society of Mechanical Engineers, reported progress.

Mr. Cooley, for Committee on National Public Works, stated that the co-operation of most of the engineering societies of the country had been enlisted and that the work of the committee was progressing satisfactorily.

The two amendments to the By-Laws proposed at the meeting, February 2, were, upon ballot, adopted.

Mr. Morehouse called up the suggestion made some time ago by Mr. Zellweger that questions propounded by Members be referred to special committees for answer, and a resolution was adopted that all such queries be placed in the hands of the respective Topical Committees for investigation and reply.

Upon motion of Mr. Cregier, the President was requested to revise the Standing Committees.

Two papers were read and discussed: "Pile Driving," by Mr. E. H. Beckler, and "Tests of Power of Locomotives," by Mr. C. H. Hudson.

The Secretary announced the death of Mr. E. B. Talcott, one of the oldest members of the Society, and the Chair, by request, appointed Mr. W. S. Pope a committee to draft a memorial paper.

Mr. Cooley offered the following:

AMENDMENT TO BY-LAWS.

In place of the term "Contributing Member" insert "Associate," and in place of the word "Associate" insert "Junior," wherever said words "Contributing Member" and "Associate" appear in the Constitution and By-Laws.

The following names were presented for membership: Horace C. Alexander, Assistant Engineer of Streets, Chicago, and Orlando H. Cheney, Superintendent of Sewerage Department, Chicago; both indorsed by Messrs. Wright, Liljencrantz and Cooke.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

At the April meeting two papers will be presented: "Truss Bridges of Long Span," by Mr. J. Freeman Clarke, and "A Revised Time-Table for Lighting Public Lamps," by Mr. J. M. Howells.

ENGINEERS' CLUB OF MINNESOTA.

SEPTEMBER 15, 1886:—Special meeting to consider plans for winter meetings. Mr. De La Barre in the chair. Present, Messrs. De La Barre, J. T. Baker, Libby, Redfield, Todd, Brooks, Sprague and Pike.

The Secretary read a communication from the Cleveland Engineers' Society, asking the club to appoint a committee to consider the subject of "The Relations of Civil and Military Engineers." The chair appointed Messrs. Abbott, Cooley and Pike as such committee, to report at next regular meeting.

Voted to make an assessment of $3 upon each member to pay running expenses.

The committee on rivers and canals agreed to present a paper at next meeting.

The President reported through Mr. Libby that he had appointed Messrs. Libby and De La Barre to act with him as a committee on Industrial Exposition. Mr. Libby also reported that Mr. Cooley had been appointed member of the Committee on Organization of the Exposition.

The Committee on Mines and Mining was requested to present a paper at the next meeting, and agreed to report at October meeting whether it would be possible.

The Committee on Weights and Measures agreed to present a paper at the December meeting. WM. A. PIKE, Secretary.

[*Adjourned.*]

NOVEMBER 13, 1885:—Regular meeting, Vice-President Abbott in the chair. There were present Messrs. Abbott, De La Barre, Brooks, Libby, Chapman, Pike, Pardee, Redfield and Sanford.

The records of last meeting were read and approved.

The committee to consider the question of sending a delegate to the Convention, to be held at Cleveland, to consider the relation of civil and military engineers, reported as follows:

Whereas, in the opinion of the committee this matter can only be reached by the efforts of each club in Congress, through the Representatives and Senators of the State and district; and in order to make such efforts effective, simultaneous action should be taken by all similar organizations: Therefore we recommend that the club send a delegate to the Convention referred to.

This report was made in substance orally, and was accepted.

It was voted to request Mr. E. T. Abbott to represent the club.

Mr. W. R. Hoag and Mr. John H. Barr were proposed for membership by Wm. A. Pike and and W. S. Pardee, and Mr. G. W. Sublette by E. T. Abbott and T. F. Chapman.

W. W. Brooks then read a paper on the "Steam Plant of the Washburn Mills," which, after discussion, was accepted, and voted to print in the JOURNAL.

[*Adjourned.*] WM. A. PIKE, Secretary.

JANUARY 8, 1886:—Regular meeting, President Geo. W. Cooley in the chair. The following Members were present: Messrs. Cooley, Redfield, James Waters, Sprague, D. P. Waters, Sanford and Pardee.

The previous records were read and approved.

Mr. E. T. Abbott, the delegate appointed Nov. 13, 1885, to attend the Cleveland meeting, not being present, and not having sent in a written report, President Cooley reported that there had been important discussion at the Cleveland meeting of the relation of civil and military engineers, and the expressed opinion was that civil engineers, both as individuals and as a body of professional men, were undoubtedly entitled to some of the Government work now in the hands of military engineers alone.

The matter having been freely discussed, the Club balloted for new members; Messrs. Hoag, Barr and Sublette being duly elected.

The President read his annual report, which was accepted and filed.

The following officers for 1886 were elected: *President*, D. P. Waters: *Vice-President*, E. J. Abbott; *Secretary and Treasurer*, Walter S. Pardee; *Librarian*, W. W. Redfield: *Representative on Board of Management Engineering Association*, Geo. W. Cooley.

On motion, Prof. Wm. A. Pike was relieved from payment of future dues on account of the invaluable aid he had given the Club in the capacity of Secretary and Treasurer, and on account of his dangerous illness, which made it doubtful if he would ever be able to assume further duties.

On motion, the club periodicals were ordered bound.

[*Adjourned*] WALTER S. PARDEE, Secretary.

FEBRUARY 12, 1886:—Regular meeting, President D. P. Waters in the chair. Present, Messrs. Waters, Abbott, Redfield, James Waters, Sanford, Barr and Pardee.

Previous records were read and approved.

Mr E. T. Abbott, delegate to the Civil Engineers' Convention held at Cleveland, Dec. 3, 4 and 5, 1885, made a report that being subpœnaed to attend a session of the Supreme Court while on his way to the Convention, he was able to appear at the Convention only in time to approve in writing the action of the Convention, and by that approval be considered a member of "the Temporary Civil Engineers' Committee on National Public Works."

Mr. Abbott detailed the work of the Convention, and explained the stand taken with reference to the organization of the Permanent Committee on National

Public Works; recommending that the club act at once, according to the instructions sent out by Mr. T. Blunt, Secretary Executive Board.

On motion, the report was accepted.

On motion, the Librarian's report for 1885 was accepted and ordered filed.

On motion of Mr. D. P. Waters, Mr. Platt B. Walker's name was proposed for membership, the name being certified to by Messrs. D. P. Waters and W. W. Redfield.

Under suspension of the rules, Mr. Walker was duly elected a member.

Mr. John Lamb was proposed for membership, certified to by Messrs. Abbott and James Waters.

On motion of Mr. Abbott for the appointment of a Permanent Committee on National Public Works, the President appointed Messrs. Platt B. Walker, E. T. Abbott, James Waters and George W. Cooley; and Mr. Walker was appointed delegate to the coming General Convention.

On motion of Mr. Abbott, a committee of three was appointed to consider the matter of rooms.

Mr. W. W. Redfield read a paper on a "Table of End Areas," which was accepted and ordered printed in the JOURNAL.

The President appointed the standing committees for 1886 as follows:

Library—Librarian, President and Vice-President.

Bridges and Materials—F. L. Straw, F. Plummer.

Railroads and Transportation—J. W. Kendrick, M. D. Rhame.

Sewers and Drainage, Streets and Paving—A. Rinker, W. D. Van Duzee.

Engineering Jurisprudence—F. L. Straw, G. W. Cooley.

Buildings—W. S. Pardee, Fred. Kees.

Rivers and Canals—G. W. Cooley, J. H. Baker.

Surveying and Topography—W. W. Redfield, E. T. Abbott.

Weights and Measures—W. W. Redfield.

Machinery—James Waters, R. H. Sanford.

Water Supply—James Waters.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE LOUISVILLE CEMENTS.

BY THOS. D. MILLER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read December 16, 1885.]

Practically all the cement used in this market is Louisville or Portland cement. At least 95 per centum of all the natural cement used in St. Louis is Louisville cement. There are various reasons for this, principal among which is that Louisville cement is the cheapest for its quality that can be obtained, and any other cement that might be brought here, were it superior to Louisville, in all probability would not be enough so to justify the additional cost, for if the quality required is beyond what the Louisville works can supply, it usually pays to use Portland, which is now quite cheap compared to what it was formerly.

So much has the Louisville cement been used in this section and with such satisfactory results, that nearly all the specifications for railroad and municipal work call for a cement equal to the best Louisville cement. The latest specifications of the Missouri Pacific Railway for mortar are as follows: "The mortar for all the work shall be of the best brands of fresh Louisville cement, and clean, sharp sand, etc." The specifications of the Street Department of St. Louis for the foundation of reconstructed paved streets in regard to the cement used in making the concrete are as follows:

"*Cement.*—The cement used shall be hydraulic cement, equal in all respects to the best Louisville cement. It shall be newly made, fine ground, and capable of withstanding a tensile strain of forty (40) pounds per square inch of section, when mixed pure and made into test bars and exposed thirty (30) minutes in air, and twenty-four (24) hours or more in water. Cement in bags or packages not branded with the name of the

maker will not be received. Samples for testing shall be furnished in such manner and at such times as may be required. On all casks or packages accepted, such inspection marks shall be placed as may be required, and the contractor shall carefully preserve these marks, and not allow them to be imitated. The cement shall be kept under cover and dry until used, and any cement exposed to the weather after testing shall not be used. Cement may be re-inspected at any time when the Street Commissioner shall so direct, and, if not found to be of proper quality, it shall be rejected. All rejected cement shall be at once removed from the line of the work."

Finding an article so generally used, it is of interest to know something of the history and growth of the industry, and also to know, if possible, what the best brands of Louisville cement are, and what they are capable of.

The geological formation to which the stone belongs from which the cement is manufactured is Devonian. To the east are found the outcroppings of the Upper and Lower Silurian, while to the west are the Subcarboniferous and Carboniferous.

The properties of this rock for cement manufacture were first discovered on the Falls of the Ohio River in 1828 or 1829, at the time the excavation for the Louisville & Portland Canal was being made. After various experiments with the rock, temporary works were erected by Mr. John Hulme, where he made the cement for the construction of the locks of that canal. The excellent quality of the cement was soon ascertained, and permanent works were established on the falls where water-power was available. On the site of this mill now stands what is known as the "Falls Mills," manufacturing the "J. Hulme Brand," one of the star brands. There was operated for many years a mill on the Indiana side of the river opposite the Hulme mill, but it has been out of use for a number of years, and now scarcely more than picturesque ruins are to be seen.

MILLS MANUFACTURING LOUISVILLE CEMENT.

NAME OF MILL.	Erected.	Owned by.	Daily capacity.	Location.	Manufactures.
			bbls.		
Falls	*1830	Louisville Cement Co.	750	Falls of Ohio River, Ky.	J. Hulme Brand, Star.
Speed	1869	Louisville Cement Co.	1,000	Speed's Sta., Ind.	Speed Star Brand.
Queen City	1870	Louisville Cement Co.	350	Watson's, Ind.	Qneen City Star Brand.
Falls City	*1867	Union Cement & Lime Co.	1,000	Near Sellersburg, Ind.	Anchor Brand.
Canal & River.	1871	Union Cement & Lime Co.	550	On Louisville & Portland Canal, Ky.	River Diamond Brand.
Black Diamond	1869	Union Cement & Lime Co.	400	Near Cementville, Ind.	Black Diamond Brand.
Silver Creek	*1872	Silver Creek Cement Corpora'n.	550	Cementville, Ind.	Black Acorn Brand.
Fern Leaf	1880	Ohio Valley Cement Co.	550	Near Cementville, Ind.	Fern Leaf Brand.

* About.

The aggregate capacity of all the mills is 5,150 barrels per day.

The Western Cement Association was established in 1870, and acts as selling and shipping agent for all the mills, thereby making the aggre-

gate office expenses about the same that each company would be under were they operating entirely independent of one another.

No record of the total sales of Louisville cement was kept prior to the formation of the Western Cement Association, 1870, but from that year on there has been, and considerable increase is shown.

ANNUAL SALES OF LOUISVILLE CEMENT FOR PAST FIFTEEN YEARS.

	Barrels.		Barrels.
1870	320,150	1878	313,372
1871	377,963	1879	350,625
1872	375,970	1880	382,119
1873	416,867	1881	627,741
1874	364,043	1882	708,598
1875	333 030	1883	863,822
1876	286,216	1884	828,794
1877	287,043		

In 1883 St. Louis handled 125,000 barrels, or about 14 per cent. of the output, and in 1884, 95,000 barrels, or about 11 per cent. of the total sold.

The largest markets for this cement are St. Louis, Chicago, Cincinnati, Pittsburgh, Cleveland, Detroit, Minneapolis, St. Paul and Kansas City, while in the territory south and southwest of Louisville it is used almost exclusively. The product of the Hulme and River Diamond mills is shipped principally south by water and rail; that of the other mills is shipped by rail to from Pittsburgh on the east to the Rocky Mountains on the west.

The quarries which supply the two Kentucky mills are partly adjacent to the mills and partly at the head of the falls. The ledge in these two localities is composed of three strata, making jointly a thickness of about nine feet. The stone is quarried during the months when the river is low, say from May to December. The same vein of cement rock comes to the surface at several places in Clarke County, Indiana, opposite Louisville, but at all these points it is thicker than on the river, the total thickness ranging from twelve to thirteen feet. All the quarries are worked open, as the stripping is so light that mining has not become necessary. Power drills are used exclusively, and the stone is hauled from the quarries of the Hulme and River Diamond mills by narrow-gauge locomotives, and piled up at the mills convenient to the kilns.

Above the strata of cement rock is a stratum of bastard cement rock which contains a good deal of flint, and overlying this is a coarse limestone, both of which are thrown away as useless. This bastard stratum is found in all the quarries. As already stated, the cement rock lies in three strata. The upper ones make as a rule a quicker setting and darker cement than the lower one; they also require harder burning.

The Hulme mill runs by either steam or water power, having a 7-foot turbine with about 11 feet fall, developing about 350 horse-power. All the other mills are run by steam power.

The coal used exclusively in the kilns is first and second pool Pittsburgh.

A perpetual kiln is used, measuring about 9 feet diameter at the top, and from 10 to 10.5 feet diameter at the bilge, and about 32 feet in height.

The crusher is made of chilled metal and is composed of a conical shell, with crushing ribs on the inner surface and a core attached to a revolving shaft. This core is composed of two parts, the lower one wearing out much sooner than the upper, thus allowing either part to be replaced independently of the other.

The grinding is done with the ordinary flint mill buhrs.

The cement rock is placed in the kiln in about 1 foot layers and the coal is scattered over each layer of stone. The burned stone is drawn from the bottom after remaining about 3 days in the kiln; it is loaded on dump cars and drawn with a cable on an inclined plane to the top floor of the mill, dumped into a hopper and fed to the crusher; it passes from the crusher in sizes varying from that of a hazel nut to powder, goes to the buhr on the floor below the crusher, where it is ground and is conducted through pipes to the bottom floor, where it is packed in barrels by power packers.

The cement has a temperature of about 110° Fahr. when it leaves the buhr, consequently, it is allowed to stand 24 hours before the barrels are driven and nailed for shipment.

The stone at the quarry is selected before it is sent to the kiln. It is again picked over after being burned, when all stone not sufficiently burned or over burned is taken out and proper disposition is made of it.

One cubic yard of broken stone, ready for the kiln, will make about 5½ or 6 barrels of cement. The quarries seem to be inexhaustible, and the present capacity of the mills is largely in excess of the demand. In the last five years the demand for cement in bags has increased very much for large jobs, where the work is near the line of transportation and proper storage is practicable, but at least four-fifths of the cement is shipped in barrels. The mills are situated in the midst of a large oak bearing district, from which the supply for barrels is drawn, thus enabling them to furnish excellent cooperage.

The price of cement has decreased from $2.75 per barrel in 1868, to prices ranging from 85c. to $1.00 at the works at the present time.

The United States Government instituted elaborate tests at the works on the Sault Ste. Marie Canal, the results of which were so favorable to Louisville cement that it was used exclusively in that work. In the spring of 1883 the work of the inspection of the cement to be used in the concrete foundations of the streets being reconstructed was assigned to the writer. The specifications under which this inspection was made have already been given. The department furnished an old style Fairbanks testing machine with the spring scales and shot pan. The molds were one inch section with circular ends similar to an eye-bar. The writer soon discovered that a great deal of time was lost in pouring shot into a pan and back again into a sack. The pan was detached and a strong wire put in its place, which passed down through the bed of the machine and was securely fastened underneath, so that by screwing up on the centre fulcrum the strain was applied to the briquette and indicated on the scale. Not having a self-registering hand attached, the scale was watched and the reading taken at the instant the sample broke. It soon became apparent that a transverse strain was often applied, caused by the inaccurate fitting of the clutch on the end of the briquette. To overcome this fault a pair of clutches was constructed with gimbles so applied that the clutch could adjust itself regardless of the uneven fitting of the sample. These clutches gave very satisfactory results.

The samples were Louisville cement, mixed about the consistency of mortar to be used in brick work, and tested. All tests were made in tension.

SAMPLES EXPOSED 30 MINUTES IN AIR AND 24 HOURS UNDER WATER

Brand of cement.	Stood 40 lbs. or more.				All tests		
	No. of tests.	Average lbs. break. stress.	Lowest	Highest	No. of tests.	Average lbs. break. stress.	Lowest
Hulme Star	419	92.7	41	154	424	91.9	20
Speed Star	476	70.4	40	168	536	64.2	00
Queen City Star	104	75.7	40	134	105	74.0	36
Black Acorn	221	67.3	40	130	234	64.8	10
Fern Leaf	167	69.1	40	140	188	64.0	00
Anchor Brand	123	70.0	40	120	137	66.3	30
River Diamond	49	71.1	48	111	50	70.2	30
All brands	1,559	76.1	....	....	1,674	72.2	...

SAMPLES EXPOSED 30 MINUTES IN AIR AND 2 DAYS UNDER WATER.

Brand of cement.	Stood 40 lbs. or more.				All tests.		
	No. of Tests.	Average lbs. break. stress.	Lowest	Highest.	No. of tests	Average lbs. break. stress	Lowest
Hulme Star	120	96.8	45	135	122	95.7	30
Speed Star	73	76.1	40	150	80	72.2	21
Queen City Star	36	76.2	45	100	45	63.4	00
Black Acorn	83	74.5	42	120	83	74.5	42
Fern Leaf	23	81.6	42	100	23	81.6	42
Anchor Brand	53	67.7	44	130	53	67.7	44
River Diamond	9	81.5	59	160	9	81.5	59
All brands	397	81.3	..	....	415	78.7	..

SAMPLES EXPOSED 30 MINUTES IN AIR AND 3 DAYS UNDER WATER.

Brand of cement.	No. of tests.	Average lbs. break. stress.	Lowest.	Highest.
Speed Star	1	86.0	86	86
Black Acorn	8	74.2	50	100
Anchor Brand	19	72.0	41	100
All brands	28	73.2	..	....

Three samples of Speed Star, 30 minutes in air and 4 days under water, gave 120, 95 and 100 pounds respectively; average, 105 pounds.

Two samples of Anchor Brand, 30 minutes in air and 6 days under water, gave 62 and 84 pounds respectively; average, 73 pounds. One sample of Black Acorn, under same conditions, gave 92 pounds.

Four samples of Hulme Star, 30 minutes in air and 7 days under water, gave 140 pounds for 3 of them, and 100 pounds for the other; average, 130 pounds. Ten samples of Hulme Star, 30 minutes in air and 10 days under water, gave 90 pounds for the highest, 60 pounds for the lowest; average, 73.9 pounds. Two samples Speed Star, under same conditions,

gave 60 and 70 pounds respectively. One sample River Diamond, under same conditions, gave 70 pounds.

SAMPLES 30 MINUTES IN AIR AND 50 DAYS UNDER WATER.

BRAND.	No. Tests.	Average.	Lowest.	Highest.
Hulme Star	16	164.3	100	202
Speed Star	4	123.7	110	140
Anchor Brand	2	127.5	125	130
Louisville Sacks	3	128.3	125	130
All brands	25	150.6	...	....

The coarse particles of Hulme Star cement stopped by a No. 60 sieve were taken mixed with the fine portions which passed a No. 60 sieve and allowed to stand twenty-four hours in air with the following results:

All coarse particles broke at 4 lbs.; 90 per cent. coarse particles broke at 20 lbs.; 80 per cent. coarse particles broke at 40 lbs.; 70 per cent. coarse particles broke at 78 lbs.; 60 per cent. coarse particles broke at 105 lbs.; 40 per cent. coarse particles broke at 121 lbs.; 30 per cent. coarse particles broke at 160 lbs.

To ascertain of what value the coarse particles were, if ground, a portion was taken and triturated until it all passed a No. 60 sieve, molded and allowed to stand thirty minutes in air and twenty-four hours under water, and broke at 62 pounds, only 10 pounds less than the average of all brands for the same age.

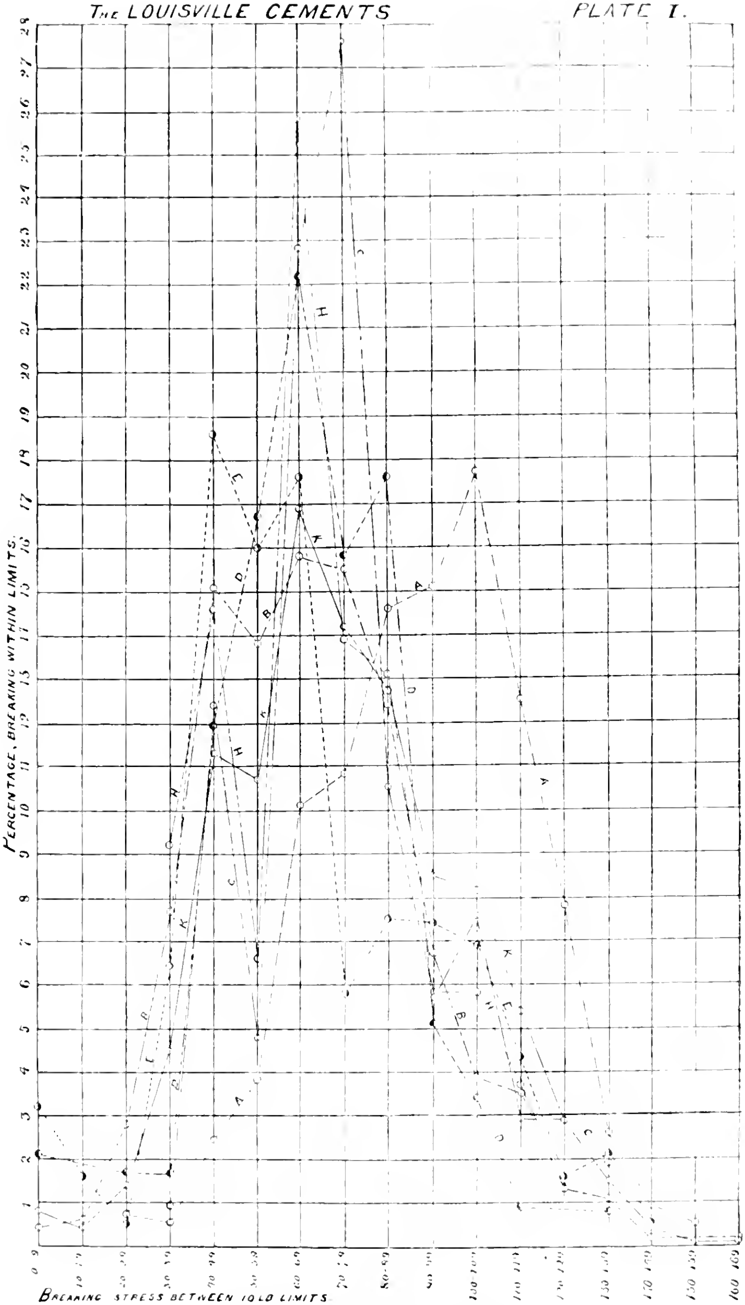
The table below shows the per centum of samples breaking within the limit of 10 pounds beginning at 0 and going to 170 pounds by tens. The accompanying cut expresses graphically what is shown in the table. These experiments extend over a period of about three years, the working months of 1883–4–5:

Before closing this paper I wish to acknowledge my indebtedness to Mr. J. B. Speed and Mr. B. J. Horton, of the Louisville Cement Association, for their assistance in gathering the facts set forth in the first part of this paper.

TABLE SHOWING DISTRIBUTION OF TESTS 30 MINUTES IN AIR AND 24 HOURS UNDER WATER.

BRAND.		Total	0 to 9	10 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79
o— — — — — — —o(A)	No.	424	0	0	3	2	10	16	43	46
Hulme Star	Per cent.	100	0	0	0.7	0.5	2.4	3.8	10.1	10.8
o— – – – — – ——o(B)	No.	536	2	3	15	41	81	74	85	83
Speed Star	Per cent.	100	0.4	0.6	2.8	7.7	15.1	13.8	15.8	15.5
o– – – ——– – – –o(C)	No.	105	0	0	0	1	13	5	24	29
Queen City Star	Per cent.	100	0	0	0	0.9	12.4	4.8	22.8	27.6
o— – – – – – – – —o(D)	No.	234	5	0	4	4	28	39	52	37
Black Acorn	Per cent.	100	2.1	0	1.7	1.7	12.0	16.7	22.2	15.8
o- - - - - - - - - - - - - -o(E)	No.	188	6	3	1	12	35	30	33	11
Fern Leaf	Per cent.	100	3.2	1.6	0.5	6.4	18.6	16.0	17.6	5.8
o—- - - - - - - - - - -o(H)	No.	137	0	0	0	14	20	9	34	19
Anchor Brand	Per cent.	100	0	0	0	9.2	14.6	6.6	25.8	13.9
River Diamond.	No.	50	0	0	0	1	3	7	12	13
	Per cent.	100	0	0	0	2.0	6.0	14.0	24.0	26.0
o————————·o (K)	No.	1674	13	6	23	75	190	180	283	238
All brands	Per cent.	100	0.8	0.4	1.4	4.5	11.3	10.7	16.9	14.2

THE LOUISVILLE CEMENTS   PLATE I.



A Hulme Star · B Speed Star · C Queen City Star · D Black Acorn · E Fern Leaf ·
H Anchor Brand · K All Brands ·

TABLE SHOWING DISTRIBUTION OF TESTS 30 MINUTES IN AIR AND 24 HOURS UNDER WATER.
(Continued.)

Brand.		80 to 89	90 to 99	100 to 109	110 to 119	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169
o————o(A) Hulme Star	No.	62	64	75	53	33	11	4	2	0
	Per cent.	14.6	15.1	17.7	12.5	7.8	2.6	0.9	0.5	0
o————o(B) Speed Star	No.	61	36	21	19	7	6	1	0	1
	Per cent.	11.4	6.7	3.9	3.5	1.3	1.1	0.2	0	0.2
o————o(C) Queen City Star	No.	11	6	8	3	3	2	0	0	0
	Per cent.	10.5	5.7	7.6	2.9	2.9	1.9	0	0	0
o————o(D) Black Acorn	No.	41	12	8	2	0	2	0	0	0
	Per cent.	17.6	5.1	3.4	0.9	0	0.8	0	0	0
o-------o(E) Fern Leaf	No.	14	14	13	8	3	4	1	0	0
	Per cent.	7.5	7.4	6.9	4.3	1.6	2.1	0.5	0	0
o————o(H) Anchor Brand	No.	18	8	8	5	2	0	0	0	0
	Per cent.	13.1	5.8	5.8	3.7	1.5	0	0	0	0
River Diamond	No.	6	3	4	1	0	0	0	0	0
	Per cent.	12.0	6.0	8.0	2.0	0	0	0	0	0
o————o (K) All brands	No.	213	143	137	91	48	25	6	2	1
	Per cent.	12.7	8.5	8.2	5.4	2.9	1.5	0.4	0.1	0.1

FROGS AND SWITCHES.

By George T. Sampson, Member of Boston Society of Civil Engineers.

[Read January 20, 1886.]

The use of frogs and switches would, perhaps, better define the particular direction to which I propose to confine my remarks, for I do not intend to enter into any particular description and comparison of the details and merits of the different kinds in use; but rather to a consideration of some of the rules and principles which govern their use; to a discussion of some of the mathematical problems involved, and the direction and extent to which they should be applied in the actual work of track-laying; and to a consideration of simple ways of platting in planning their arrangement in yards.

Let me first explain that it is intended that this paper shall apply only to the use of frogs and switches on steam railroads, where locomotives are used, and not to them as they are used on street railways for horse cars. In the latter case, especially in our own city of crooked streets, where short and constantly varying radii are used for switch curves, it would be found impracticable to adopt such methods as are herein recommended, and careful accuracy is absolutely necessary, in order to secure good track.

The calculation of the elements of turnouts, such as the frog angles, switch angles, lengths of leads, and radii of switch curves render necessary as full and correct a knowledge of geometry and trigonometry as do any other problems which an engineer is likely to be called upon to perform; and, when once undertaken, results of extreme nicety can be obtained with nearly or quite as little labor as approximations can be arrived at. It is on this account, and because the limits, within which the theory of the calculations can be correctly applied, are almost infin-

ite, and because every engineer having to do with frogs ought to be thoroughly conversant with all of these principles that many engineers who are thoroughly able men, and thoroughly competent to superintend the construction of the bridges, masonry and earthwork of a line of railway, make but a poor showing if suddenly called upon to lay out the tracks of a railway yard without having had previous practical experience in this specialty. To a beginner the subject seems peculiarly intricate and puzzling, and I have often wondered as to what extent Robert Stephenson, the father of railroads and locomotives, experimented before arriving at satisfactory results. In the old times, and even up to comparatively recent years, when called upon to lay out a line switching off to right or left of the main track it was customary to assume a curve of a degree best suited to fit the ground desired: to lay it out tangential to the main track and afterward calculate the length of lead, frog, angle, etc., required. It is easy to imagine the errors and perplexities into which the pioneers might have been led on account of lack of practical experience in these matters, and it is more than likely that costly changes have more than once been rendered necessary. The theory of the calculations will apply quite correctly with a twenty or thirty minute or other easy curve for a switch curve; but frogs cannot be made to do service with points thinner than about one-half an inch, and it is not advisable to have switch rails of excessive length, or longer than rails are commonly rolled at the mills, as they would necessarily be should such curves be adopted for switches.

For the sake of simplicity and that the subject may be more easily understood, I am assuming that the switch curves are laid off to the right or left of a straight main track. The matter of laying out switches from a curved main line does not vary essentially in practice, and the only difference consists in the change of radius of the switch curve. As above stated, frogs must have a thickness of about one-half an inch at the point, and further than this the taper or angle of the point must not be too acute; that is, it must be sufficiently large so that the distance used in crossing the width of flange way, of 1¾ to 2 inches, on the acute angle will not be so great as to afford insufficient support for the car wheels passing over it. Moreover, the variation in the wheel gauges of cars of the different roads is so great that the wheel flanges are often likely to pass on the wrong side of the frog point if it be very acute. It is plain that the radius adopted for the switch curve governs and determines the angle of the frog, and while on the one hand we can calculate a frog angle for a curve of any radius, we find on the other hand that we can construct frogs which will be practical and safe for use only within certain limits. These limits have been found by experience to be between an angle of 3° 11′, or a switch curve of 3,540 feet radius for an extremely acute angled frog, and in the other direction we are only limited by the sharpest curve around which the rolling stock can travel. The angle of 3° 11′ is that of a frog having a spread of one foot in eighteen (called a No. 18). I have named this angle as a limit because it is that of the longest frog I have ever heard of. It is, however, only on rare occasions that frogs as long as a No. 14 or No. 12 are required, and in ordinary practice these are considered very long frogs and not desirable. As in all

other cases, it is seldom necessary or well to go to extremes, so in the use of frogs it is always best to use the average or medium angles. Even within these average limits the choice of angles offered is very great.

In times past it was the custom to go upon the ground, assume the position for a proposed new frog, determine the direction in which it was desired to go, and by, perhaps, using a transit, stretching a string, or by some other less accurate method, ascertain the distance in which a spread of one foot was obtained, and then have a frog made at the railroad shops. This, of course, resulted in a great diversity of angles, and scarcely any two frogs were made alike or were interchangeable. This practice was finally superseded by that of making frogs having a spread of 1 foot in 6 feet, 1 in 7, 1 in 8, 1 in 9, 1 in 10, 1 in 11, 1 in 12, etc., and with this variety there was ample room for choice in all cases. Probably in the majority of the railroads of this country the roadmasters are free to select any one of the above named frogs which they may see fit, but it is surprising to see to what extent even this variety can be narrowed down. In the issue of the *Railroad Gazette*, published December. 4, 1885, there are shown drawings of the "Standard Turnouts and Crossings of the Pennsylvania Railroad." These drawings show the use of No. 8 and No. 10 frogs for turnouts and cross-overs, and also a three-throw switch for No. 8 frogs. A three-throw of No. 8 frogs requires a No. $5\frac{7}{10}$ crotch frog. As per these drawings we see the choice of the P. R. R. narrowed down to three angles, and for work on the main line, outside of yards, the room for choice is ample. As far as it is possible to lay down a rule for such cases my own opinion would be that a choice of two frogs, a No. 9 and No. $6\frac{1}{2}$, would be as good as the three above named. A No. $6\frac{1}{2}$ is the proper crotch frog for a three-throw switch of No. 9 frogs. For proper reasons I should prefer a No. 9 frog before either a No. 8 or No. 10. With reference to the question of safety and practical utility of the frogs themselves, there is scarcely room for choice between a No. 8, a No. 9 and a No. 10, but the curvature of the switch lead varies respectively from a 10° to an 8° and 6° 18′ curve. Undoubtedly, as far as theory is considered, the easier curve is to be preferred, but it is found that the heaviest of "Mogul" and Consolidation locomotives traverse a short curve of 8°, 10°, or 12°, without difficulty, and, therefore, there is no practical reason to be urged against a No. 9, as compared with a No. 8 or No. 10. Assume some of the ruling dimensions which would seem to form the best combination for a first-class turnout and enter into a solution of some of the problems:

Let the frog angle F = a spread of 1 foot in 9 feet = Nat. sine of angle 6° 22′.

Let the switch angle S = a spread of $4\frac{1}{2}$ inches in 15 feet = Nat. sine of angle 1° 26′.

Let the gauge g be 4 feet $8\frac{3}{4}$ inches = 4.73 feet.

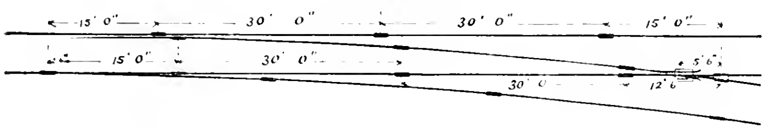
Let the space d be $4\frac{1}{2}$ inches at the heel of a 15-foot point switch.

Then by a strictly correct calculation the distance from heel of switch to point of frog should be obtained by a solution of the formula:

$$\text{Frog lead} = \frac{g - d}{\text{Sine of } \left(S + \dfrac{F - S}{2}\right)}$$

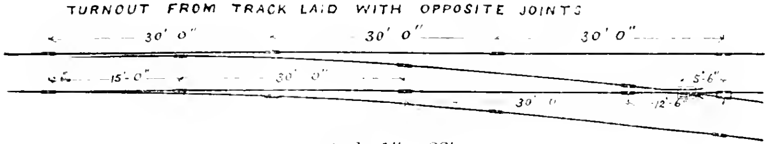
With the use of the above dimensions the solution of the formula gives a distance of 64.01 feet from heel of switch to point of frog, or a little more than the combined length of two thirty-foot rails; that is enough more to admit of a proper length of wing rail between the point and throat end of frog. In purchasing steel rails upward of 90 per cent. of quantity purchased can always be counted upon as coming in lengths of 30 feet each. These lengths are, therefore, always to be obtained readily, and any practice which accepts and allows of their use in the same form as when first received from the mill, without requiring the performance of other labor in order to work them into proper shape, necessarily results in economy. The length of 15 feet for the switch rail was assumed from the fact that a pair of points could be made from one 30-foot rail without waste of material. On the New York & New England Railroad the selection of the length of twelve and one-half feet for

TURNOUT FROM TRACK LAID WITH ALTERNATE JOINTS.



RAILROAD FROGS AND SWITCHES, FIG. 1.

TURNOUT FROM TRACK LAID WITH OPPOSITE JOINTS

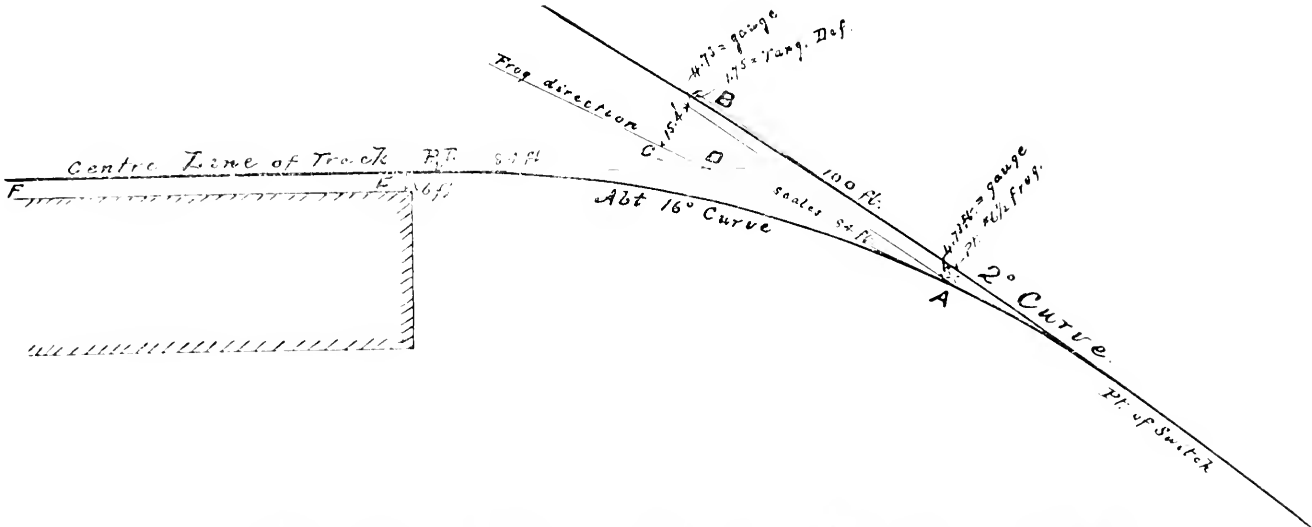


Scale, 1″ = 26′.

a standard No. 9 frog was also in part caused by the fact that one 30-foot rail would make one frog; and further, for the reason, that with frogs of this length, and with 15-foot point switches, a turnout can always be laid without cutting rails or introducing short pieces. This arrangement can be best understood by reference to the drawing Fig. 1. With the adoption of a length of 12½ feet for the frog, with 5½ feet from heel to point; with 15 feet for the length of switch rail; and with two 30-foot rails for the length of lead, a combination is effected which besides possessing the advantages of economy in material, time and labor, as far as they can be attained by the adherence to any one rule, is also one not easily forgotten or liable to be laid wrong by section foremen. In this way uniformity is easily secured. The switch lead will be three feet longer than the calculated length, and the curve will necessarily be compounded, but there will be no irregularity visible to the eye, and locomotives pass and repass day after day around curves even far more irregular than in the instance given without trouble or injury, and this theoretical objection passes for naught. I do not desire to be understood in this matter as advising that variations in switch leads could be made indiscriminately, but I wish to emphasize the idea that within the limits of reason and judgment, which is founded on a correct knowledge of the theories, supplemented by considerable practical ex-

perience, there is room for a departure from the strict rules of mathematics with advantage and economy.

With reference to platting frogs, I will try to make plain a practice which I am accustomed to follow by reference to the accompanying drawing, Fig. 2. I have assumed a case which might be a very common occurrence. Suppose it was desired to connect a track which is to run parallel and beside a building with a main track laid with a 2° curve, passing as shown in the sketch. With the use of a set of flat curves made of zinc, hard rubber or other suitable substance, on a scale say of 50 feet per inch, with one for each degree or quarter degree of curvature, I see quickly that it will require about a 16° curve to make the connection. After laying it on the plat, I select a point where the 16° and 2° curves seem to be about 4.73 feet, or gauge distance, apart, as approximately the frog point. Knowing that the curve is about 16°, and that any switch curve out of the inside of a 2° curved main line would be just about so much sharper than it would be if from a straight main line, I see at once that the frog should be of such a number as would require about a 14° curved switch lead from a straight track. The frog most nearly answering these requirements is a No. 6½. Now, having assumed the frog point at *A*, I proceed to lay off the angle as follows: First scale a chord of 100 feet along the main track. With the use of Henck's tables I see that the tangent deflection for a 100-foot chord on a 2° curve is 1.75 feet. The spread of a No. 6½ frog in 100 feet amounts to 15.4 feet, and by scaling from centre of main track at *B* a distance of 15.4 feet plus 4.73 feet (or gauge) minus 1.75 feet, the tangent deflection, the point *C* is obtained, which marks the frog direction. By drawing the line *A C* through the line *F E* produced, we obtain the point *D* as the intersection of tangents. Then, by scaling from *A* to *D* and laying off an equal distance toward *E*, we find that the *P T* falls short of but near the corner of the building. The minimum clearance distance of 6 feet is, therefore, maintained, and our trial point for the frog at *A* is, therefore, satisfactory. Had it proved unsatisfactory, it is but a short process to make another trial by moving the point of frog a few feet to right or left of the one first assumed at *A*. To complete the plat it only remains to scale off from *A* the length of lead adopted as standard for a No. 6½ frog, mark the point of switch, and draw in the switch curve. It would have been quite as easy to have ascertained the proper point for placing a frog of any other angle than that of a No. 6½, had it been so desired, by applying the same reasoning, and by substituting, in place of the 15.4 feet used at *C*, a distance corresponding to the angle of frog desired. It is more than likely that the latter case would be the one most commonly adopted in actual practice (except in entirely new work), on account of the fact that it is generally necessary to choose from frogs on hand, and select the one of an angle nearest that desired. In the present instance, the choice of a No. 6½ was caused by the desire to have a uniform curve from the point of switch to the *P T* near *E*. Had a No. 9 frog been used instead, while the curve from *A* to *E* would have been somewhat sharper than a 16°, the curve from *A* to point of switch would have been about a 10°. I say about a 10° curve, knowing that there is some variation from that figure, but not a great deal. It is



RAILROAD FROGS AND SWITCHES, FIG. 2.

Scale, 1″ = 61.5′.

not a matter of any importance to know just what the precise degree of curvature is, because the approximation satisfies me that the curve is within practical limits quite as well as would the most precise calculation. Had the main track been straight instead of a 2° curve, as shown in Fig. 2, the process of platting would have been somewhat simpler, because the consideration of the tangent deflection would not have entered the case. In laying off the frog-angles from curves, it is not always possible or advisable to use the chord of 100 feet, but to any one familiar with curves, it is but a simple matter to calculate the tangent deflection and spread of the frog for any length of chord desired. With a knowledge of these theories, and with the use of a common tape and a couple of range poles, this platting can be done upon the ground itself, and the frogs located and curves laid out with all the nicety that is commonly required in the case of single switches.

When, however, there is a considerable system of switches to be laid out, it is always best and necessary to prepare a correctly plotted plan in order that complete schedules of all material required may be prepared, and the material ordered and delivered on the premises before work is begun.

There is room for a great deal of careful and intelligent study in the arrangement of plans for switches in yards, more study, in fact, than the subject commonly receives. Too often the tracks are laid one by one, as occasion requires, in (for the time being) the cheapest possible way, and in the course of time the yard presents itself a large mass of snaky and unsightly curves, acknowledged by all to be inconvenient and expensive to operate, but yet so occupied by the rush and pressure of business, that the space can seldom be spared long enough to make a change radical enough to effect a material improvement.

The more carefully and minutely the plan is worked up beforehand, the more correct and complete can the schedule of materials be prepared; and, consequently, the use of material will be more economical and few or no delays will be occasioned for the want of special fittings. The work can be pushed with dispatch, the plan can be more closely adhered to, and the work will much more likely be presentable when finished. The degree of merit in the work when finished will depend on the qualifications and ability of the engineer in charge.

HILL-SIDE DRAINAGE.

By John L. Culley, Member of the Civil Engineers' Club of Cleveland.

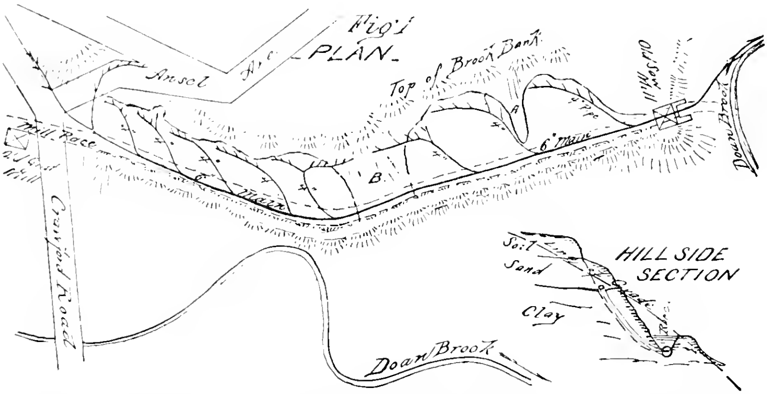
[Read February 9, 1886.]

On the left bank of Doan Brook, Cleveland, immediately to the southeast of the junction of Ansel avenue and Crawford street, stands a solitary shaft surmounted by a cog-wheel, that designates the location of the once famous Crawford grist-mill. There was a dam across Doan Brook a short distance above this mill, whence was supplied the motive power to this and to a saw-mill some 900 feet farther down stream through a mill-race, which, after crossing Crawford road, hugged the foot of the high brook-bank all the way to the saw-mill. At this lower mill, the

water, descending some 13 or 14 feet, again united with the brook 150 feet below the lower mill. These two mills were erected by the Crawfords—the grist-mill in 1816 or 1818, and the saw-mill in 1845, and were operated by the proprietors according to their convenience, the demand of their neighbors, or the stage of the water. Long since both mills have been abandoned, and, gradually falling to decay, have disappeared. Beyond the solitary shaft there is scarcely anything to designate the location of the grist-mill, while now there is not a vestige of the old saw-mill left, which three years ago was designated by a few remaining heavy timbers. The mill-race thus abandoned gradually filled up. The high brook banks were full of live springs, causing numerous land-slides, which in some cases nearly closed up the water-way. Thus it was, as time went on, that the race and the side-hill became one immense quagmire, impassable to man or beast. The bed of the race then filled with stagnant water, fed by rain and the springs above, and the side-hill was a livid body of quicksand, mud and dirty water. Besides being an unsightly object and a depreciation to the otherwise picturesque and valuable property, it gave off, during the warm seasons, a disagreeable odor, while the people in the immediate vicinity were in great danger of malarial diseases. The Heard family, of architectural fame, were for years the proprietors of this property. They and their successors made several attempts to remove from the estate this cancer; for, like a cancer, this quagmire grew larger and larger year by year. Their money was uselessly expended, for their efforts were ineffectual. It was not until the present owner, Mr. J. K. Bole, took possession of this property that a systematic plan for the removal of all these nuisances was inaugurated. Late in the fall of 1883, Mr. Bole called my attention to this matter, with the request that it be looked over with a view to its complete removal. The problem to me was a tough one, and I must confess that when the system of treatment had been adopted, I had grave doubts of its complete success, which were not removed until the system was executed.

The race was maintained by a good, strong earth embankment between it and the brook. The hill-side rose abruptly at the farther edge of the race to heights varying from 15 to 30 feet, and was composed of a subsoil of yellow sand lying on a heavy bank of hard blue clay, and under a dark surface soil. The clay, being impervious to water, was free from springs, and accounted for the presence of the numerous springs in the lighter soil above the clay; and that in the strip *A*, Fig. 1, being entirely of hard clay, we encountered no spring water, and in the wider strip *B*, same Fig., a few small springs appeared, as it was composed mainly of clay, but enough of the lighter soil to allow the passage of water over and through it. The presence of this bank of clay also accounted for the fact that the springs appeared only high up on the hill-side. It was this high location of the springs that caused all the trouble with the hill-side, and materially increased the difficulties to be overcome; for it is apparent that had the springs appeared only at the foot of the slope, the hill-side would have been little affected with land-slides, and the water could have been readily removed. Previous attempts to solve this case had been confined to efforts to remove the water by short lines of unfiltered tiles laid in

trenches up the hill side from the water-way. An examination showed that these tiles had failed either to do their work, or to effect a hold upon the steep slopes. They and the accompanying slopes had slipped down into the water-way. Evidently the complete removal of all water, either live or stagnant, was of first importance; and whatever system was to be employed, it should be of a permanent character To be practical, the work should be of the least cost. By reference to the plan (Fig. 1), it will be noticed that the springs were not confined to the hill-side within the inclosure, but existed in Ansel avenue and beyond. As these affected the hill-sides within the inclosure, they came also within the scope of our treatment.



After making a thorough survey and examination of the case, it was decided a pipe drainage would be the most effectual, and immediate steps were taken to execute the plan. First, the old race-way was opened at its lower end deep enough to remove all stagnant water, and a trench was cut throughout the whole length of the raceway in which, after all stagnant water had been removed, a six-inch pipe main was laid at a grade of 0.6 to 100, so that all water conveyed to the main would be quickly removed. Open trenches were then cut into the wet, springy slopes, and thus from them were removed all standing and live waters. When these trenches had been sufficiently drained, four-inch pipes were placed within them. From these, in like manner, two-inch pipes were carried to wherever a spring could be detected. The four-inch pipes, in order to lessen their gradients, were, wherever possible, carried across the slopes as they were carried upward All the pipes were laid in abundance of proper filtering material, to prevent the pipe filling up with silt. At the time of cutting the trenches, numerous springs were apparent, and were therefore immediately drained away. Undoubtedly there were other springs that then remained undrained, but the soil around them was too wet to allow their detection, and the system was then allowed to remove this water, that the remaining springs might be detected. It was most important that every spring be removed; for the moment the spring had gained a head whose pressure exceeded the resistance of the overlying material, it would compel the material to give way; and if many were left

thus unprovided for, the slope would soon be in its original condition. This subject of the proper removal of spring water from hill-sides upon which an embankment is to be placed, is one that has been too frequently overlooked. Within the last year an engineer of experience advocated the placing of a retaining wall at the foot of an embankment, to resist the effect of the underlying springs issuing from the hill-side above the foot of the slope. Nothing could be more fallacious. The moment the springs accumulate a head whose descending force exceeds the united resistances of the retaining wall and the embankment, both the retaining wall and the embankment will go, and often with disastrous effects beyond. Of course, the retaining wall could be made strong enough to overcome any head the water behind it might ever obtain, but would be of most extravagant construction. A retaining wall may be employed to reduce the lower slope length, but when so used every precution should be exercised to remove all water from behind it. Moreover, the stability of an embankment is materially weakened by resting on a wet foundation.

When, therefore, we had connected as many springs as could be detected, the system was left to drain the soil dry. In a surprisingly short time it was possible to walk over this territory in any direction. Small and obscure springs began now to show themselves. Wet spots on the surface, unaffected, by the drainage, indicated their presence, and they were accordingly connected with the drains. This process was repeated until all springs had been taken up. During the whole process the pipe trenches were kept open, to facilitate connections and to readily locate the lines of drainage. At the end of two months every spring had disappeared; the trenches were then filled up, the top of the hill-side graded off, and the race-way filled up. And to-day all evidences of the old water-course are gone. The total output of spring water is some 160 barrels per day, and the supply remains nearly constant the year round. Besides this area, there were several good-sized breaks in the brook bank similarly treated, making the total area redeemed more than 2 acres, at a cost of less than $1,100, or at a price less than the value of actual land reclaimed, while the whole property was thereby enhanced in value many thousand dollars.

There is much discussion as to what is the proper material for pipe filter. Planing-mill shavings were used with excellext results throughout this work. Objection has been made to them, that as they were put in places that were alternately thoroughly wet and thoroughly dry, they were perishable and would soon rot out, allow the silt to run in and fill up the pipes. My experience has been the contrary of this conclusion. Pipes laid in this filter, years ago, are now doing as good service as when first set. It makes a thorough filter, excluding the soil, while the water passes freely through it, and its capillary attraction keeps it always wet and prevents decay. It is with us the best as well as the cheapest practical filter. Hay and straw are not to be compared to it. I regard broken stone and furnace cinders both as liable to be choked up, while their cost would be an item against their use. If there is danger of the pipes filling with roots, the joints should be protected by proper bandages of cotton cloth, paper, &c. The filter material should be applied liberally throughout the whole length of the pipe, so that

when the water is conveyed to it, it will be at once carried into the pipe. If the pipe is liable to be distorted from its alignment by the load afterward to be placed upon it, it is recommended to place plank under it.

This method of treatment is best illustrated by a case handled some years ago (Fig. 2).

The location was on a hillside, about 30 feet above the foot of the hill. A pocket of quicksand some 60 feet in diameter was found between two spur slopes. The lower side of the pocket had for some reason become choked up, and a 10-foot pole failed to touch hard bottom. While the most natural way would be to have carried a drain directly into the basin, an examination showed that it was fed by numerous springs on the slope farther up than the pocket itself; and, therefore, a pipe line carried into the basin, if it had been possible, would have remedied matters but little. The springs must be drained to abate the nuisance. Pipes, therefore, were carried around on either side, and the springs drained off. The water being thus carried away from the source, the basin soon from

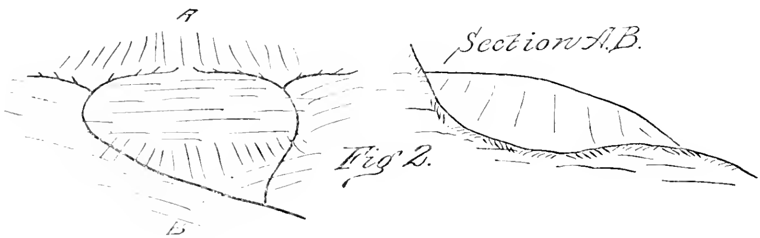


Fig 2.

natural causes dried up and ceased to be troublesome. A decided advantage of the treatment is the economical placement of the drains, and that they are used only where needed, and the water is entirely carried off. It is only just to say, in conclusion, that both these cases were executed by Mr. Henry Wood, member of this club, and to his intelligent handling is principally due their success.

ENGINEERING AND MECHANICAL PROBLEMS IN COOK'S STOVE CONSTRUCTION.

By Jos. Leon Gobeille, Member of the Civil Engineers' Club of Cleveland.

[Read January 12, 1886.]

The evolution of the cooking-stove is a subject in which I have taken much interest of late; for I have come to realize that the poetic, and much vaunted fireside, with its back-log, flickering embers and home-making influences, has gotten itself changed, in these practical times, into a simple cooking-stove, in upwards of one-half of the households of our land. Around its heat-radiating sides gather the family circle of our poorer classes; from which we will draft the bone and sinew, and, I might add, the greater part of the brain as well, of our to-morrow; and if it hold good then as now that the way to a man's heart and affections lies through his stomach, or that being well fed is the half of content

ment, then the cooking-stove is a prime factor of importance from a socialistic point of view.

Who invented this thing as we know it to-day, is a question we will not try to answer; nor will I weary you by tracing its development, in detail, from the time of that pre-historic matron, who, lighting her fire in a niche of rock by means of diligent rubbing together of rotten wood, broiled her fish or fowl upon the glowing coals; down through the Anglo-Saxon mother's time of brazier and lighted slow-match, to our own fore-mother's day of revolutionary years, whose vaulted fire-place, with crane to swing the steaming pot and stir-line to turn the toothsome bird upon the spit; she lighted her fire with the flint and steel, and doubtless sighed in pity o'er her older sister's trials.

About this time that distinguished American, Benjamin Franklin, began to be known as an investigator of the science of cookery, which grew out of his researches into the nature of heat.

Later came another American, Benjamin Thompson by name, to whom the world owes much, as he was the first to demonstrate that heat was but a mode of motion. The Bavarian king had made him Count Rumford in recognition of his services in this direction, and the well-authenticated results of his practical experiments in cookery have never been surpassed—indeed, scarcely equaled—to this day.

After Count Rumford came Dr. Eliphalet Nott, then President of Union College, who, mainly devoting his researches and experiments to stoves adapted to heating purposes, still added valuable data to our subject.

Of course, their best constructions were very crude compared with the average of to-day; but the publicity given to the results obtained by them set others thinking, and brought up, through the influence and advice of Dr. Nott, that price of stove designers, Nicholas Schwartz Vedder, who embarked in the business of designing and manufacturing stove patterns, in the then village of Troy, N. Y., in the spring of 1831, and to whom we owe the greater part of our modern conveniences in the cooking stove, either as absolute inventor or else the man who worked out the idea and made it practical. Of course many other worthy names crowd to my memory, among them being P. P. Stewart, of Troy; Denis Littlefield, of Albany; D. Harris, of Cincinnati; and Jordan L. Mott, of New York City; but brilliant as these men were and are, Messrs. Littlefield and Harris being still living, the enduring fame will be about the name of N. S. Vedder.

Notwithstanding the importance of the subject, or the fact that upward of four hundred firms are engaged in the manufacture of cooking-stoves in this country, with millions of money invested in plant and patterns, there is scarcely any literature bearing directly upon it; none whatever, in fact, excepting fugitive papers and essays only to be seen by the tedious process of search through the files of trade journals. Some have gone for knowledge to the records of notable actions-at-law between stove founders; but a more unsatisfactory text-book could scarcely be thought of; for, though upward of $100,000 were expended in a single suit to get at the truth in respect to the state of the art at the time of the issue of the patents on the so-called anti-clinker grate, the learning

shown forth in the thousands of pages of testimony would not be worth the acquirement if it cost the time necessary to wade through the printed evidence alone.

The cooking-stove we shall discuss (which, to begin properly, should be written thus: "Cook's Stove") is familiar to all of you. We will assume that the size is denominated 8–20, which means that there are four boiler holes to take 8-inch ware, and a 20 × 20-inch oven to take four 10-inch pie-pans. It is a curious fact in this connection that stove manufacturers are entirely dependent upon the makers of pie-pans for the sizes of their oven bottoms—stoves being designed to fit pie-pans, and not pie-pans stoves. We will divide the demands made upon the cook's stove designer into two general classes: the utilitarian and the mechanical. From a utilitarian point of view, the desired elements are: a fire-box, economical of fuel, and so constructed that the increased heat and consequent expansion there will not cause parts to press outwardly against their environment with such power as to crack the stove; flues so proportioned as to draw well in any kind of chimney, or even in the open air with two lengths of stove-pipe erected; an oven that will bake well on the bottom, equally over its whole surface, and brown nicely on top without danger of burning; a reservoir for boiling water, but so constructed as not to chill the oven while in use. Among the mechanical requirements are: extreme lightness of metal; great care that the plates may be molded cheaply, and cast without losing form, being strained or becoming crooked; and a realization, at every step, of these facts gained, this cook's stove of fifty or seventy-five separate pieces must go together with so little fitting that the entire cost for labor, from being shaken out of the sand to the inspection of the finished stove, shall not exceed $2.50, and that the interchangable system of parts is absolutely required.

The mechanical difficulties to be overcome by the designer; the excep tional skill demanded of the pattern-maker; the care and expertness required of the molder; and the intricacies of movement and nicety of placement demanded to properly mount together so many pieces of very thin cast iron, so that they will stand shipment long distances, and meet the requirements of daily use in the hands of persons notably unskilled in mechanical manipulation; these are some of the points I wish more particularly to dwell upon at this time. The first thing to do if you contemplate building a cook's stove is to make a rough perspective sketch of an original design in ink or charcoal; from this make your working draft (Fig. 1); the section black, the plan red, and the alterations or changing pieces green.

Very likely you will be required to make your stove a given weight, in that event the calculations must go on while making the drawing and will be in the nature of a recreation from the arduous labors of the day. Again you may have bound yourself to make the patterns for a certain fixed price, and within a definite time; which price and time may be the closest that could be made, by a close stove founder, in a close year; in such a case you will have more recreation.

You will bear in mind that while shrinkage must be added to all pieces, which of course means two shrinkages to the master patterns, some

forms will shrink more than others, and, as this variation has never been formulated, one has nothing but personal judgment and experience for a guide.

Some plates and parts of plates, notably about the fire-box, will expand more than others; because of their proximity to the intense heat; and will need be designed with plenty of clearance or play; when fastened by bolts, they should pass through holes elongated in a plane with the line of expansion. As violent expansion of cast iron by heat is never taken entirely up in cooling, the parts must be made by means of flanges or other devices, to take up the space lost through movement.

Some peculiar and intricate problems arise to torment the designer and test his knowledge of mathematics and expedients: *e. g.*, where the flues of the cook's stove turn from the back to the bottom, there is a point which is very difficult to proportion correctly, because of its irregular shape. I have been in the habit of delineating a section of this part of the flue on a certain quality of stiff bristol-board, carefully calendered,

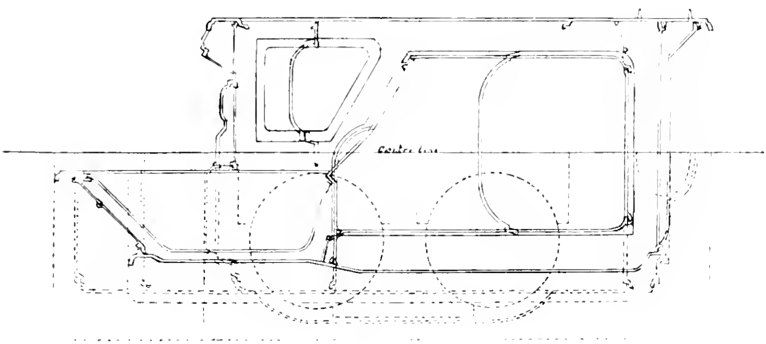


Fig. 1.

cutting to the outline and weighing on a delicate balance, using pieces of the same board, one inch square, as weights. This method, giving the area in inches, is simple, accurate and rapid. To determine if the capacity of a flue, at any given point of irregular outline of section, is equal to that of the pipe-collar, I have employed the same idea, using a piece of bristol-board the size of the pipe-collar exit as a weight. In estimating the weight of a cook's stove from the wood patterns, the ordinary practice is to weigh the patterns, allowing a pound of iron for each ounce indicated, adding thereto 10 per cent. This method is fairly accurate with patterns made entirely of wood; but take an oven door for example: after it is ornamented and there are other materials to account for, composition, varnish, and very often lead—if the ornamentation be heavy and bold. Estimating weight by this formula on such a pattern is like looking at the sun to tell the time of day—you will make a close guess perhaps, but it will be only a guess. To get accurately at the solution of such problems I made a tank 24 × 36 inches, and 12 inches deep, and for three inches of the top I graduated a scale into 64ths of an inch. This tank was leveled up and filled with water to the lower line of the scale,

The pattern, well varnished, was plunged for a moment into the tank, the displacement noted by means of a floating device which caused an indicator to be raised and temporarily maintained at the flood height, then the pattern was taken out and wiped dry. If the reading of the scale showed a rise of one-eighth inch, then I knew that the casting under ordinary circumstances would weigh 31 pounds when set up in the finished stove. The constancy and accuracy of this method is marvelous, and has been a source of wonder to many foundrymen, to whom I show my simple expedient for the first time. This idea, though as old as Archimides, will be a surprising novelty to many.

The fire-back, end linings, covers, centres, and grate are particularly exposed to the force of excessive heat, which acts very powerfully as an impingent, as in the case of the covers and centres directly over the fire-box, or, more trying still, as seen in fire-backs, which are attacked for hours at a time by a viscous, clinging mass of flameless incandescence. The best practice now is to make each fire-back in three or more interchangeable pieces, with a chamber directly back of them, providing abundant means for the ingress and egress of air through orifices in the sides or jambs of the stove, thereby insuring a free circulation. This air-chamber should contain about two and one-half times the cubic contents of the lining, a vertical section being the reverse of analogous to a similar section of the fire-back ; *i. e.*, where the section of the iron is thin, the space behind should be correspondingly ample. Now, since the pieces in the center of the back-wall of the fire-box will burn out much faster than those on the ends, the motive of sectional fire-backs is apparent, the intention being to exchange, or rather to transpose, the end and centre pieces when the condition of the latter show signs of fatigue. The life of a sectional fire-back is about equal to three of the ordinary sort. In pieces like centres and covers, where there is a forcible thrust of tongues of flame directly against the surfaces, a double plate should be used, with adequate means of ventilation at the top. Great care should be exercised in designing top plates, because frequently, through the carelessness of servants and children, large quantities of cold water are precipitated over the top surface of the stove when very hot, thus causing sudden cooling, and often inducing the plates to crack in their efforts toward a readjustment of the particles necessary to produce contraction. Upon the ends of plates there will be considerable makage—fully one-sixteenth inch in some mixtures of iron, and even more in cases of careless manipulation by the molder. This resultant is seldom taken into account by the designer, few having a definite knowledge of the fact, though it is quite an important item, and should not be overlooked. Makage is traceable to two causes—first, to the fact that while molten iron, at the instant of cooling to rigidity, expands slightly, it is not an equal expansion, the enlargement of a plate being considerably more at the boundaries of its area than in its thickness ; the second incentive to makage is excessive rapping of the pattern by the molder just before the process of drawing it from the nowel. Unequal thickness in a plate, unless proportioned with great care and judgment, will cause the plate to cool unequally, be under a strain, and very likely fly to pieces at the slightest provocation. Your

completed stove must have as few bolts as possible, and not a single drilled hole in the entire construction, while the flues must be easy of access for removal of soot and ashes. In order to impress the mechanical construction of a three-flue stove upon your memory, I have caused to be made of tin and glass a model of a cook's stove of the wood-burning type, which is one half size, and in which I will now make a fire that you may see it at work (Fig. 2).

The sort of pattern-maker technically known to engineers as a "shoemaker" does not flourish where stove patterns are made; nor are the traditional broadax and frame-saw all the tools needed for the work: the

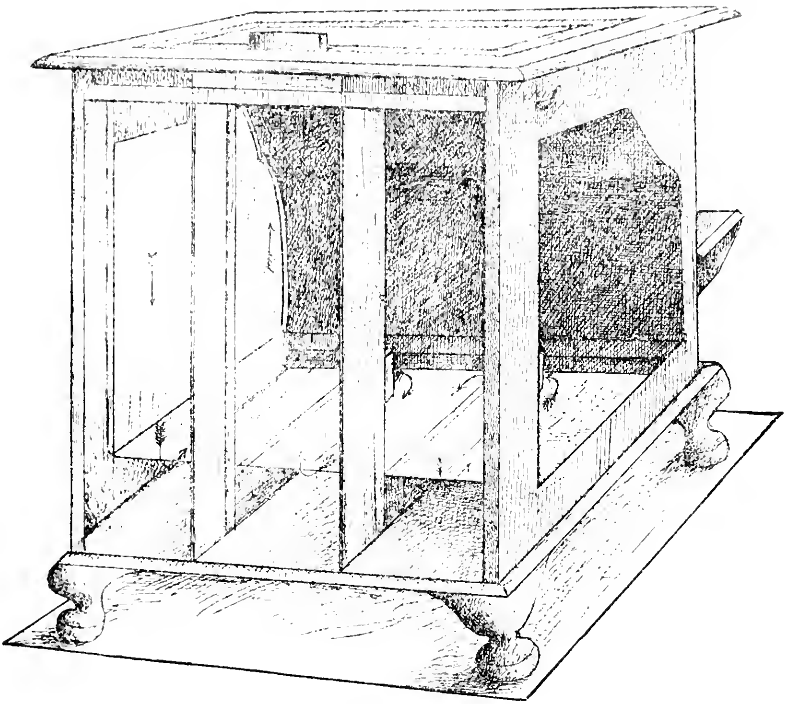


Fig 2

special hand tools in use which have never been manufactured for sale, or in fact known of outside the pattern shop, would, in the description of their forms and uses alone, give ample material for an interesting paper. The wood of which stove patterns are made is of the best select uppers, commonly called "cork pine," and the thickness of the stock grades from one-fifteenth inch to one-fourteenth inch, one-twelfth inch, one-tenth inch, etc., up to three-sixteenths inch, the principal thickness used being one-fourteenth inch. The difference in thickness between one-fourteenth inch and one-twelfth inch is not very great, only one-eighty-four inch, but even this apparently slight discrepancy will upset all one's patient and painstaking calculations in the very important mat-

ter of weight; the mere getting out of the material then is of considerable importance, the planing up of "thin stuff" for particular work is so delicate an operation that the workman must learn to discriminate between a dry and humid condition of atmosphere when proving by standard caliper newly planed stock. As the followboard is first gotten out and afterward covered by the requisite thickness of wood (first carefully applying two coats of shellac and one of oil to the form to prevent the pattern sticking at the glue joints), some fine points of construction are developed on intricate forms, as for instance hearth bottoms for wood cook's stove, which sometimes puzzle the brightest mechanic, as can be easily conceived by trying to keep in mind two shrinkages, one makage, a thickness of stuff and the fitting point above and below, upon so simple a form as a hollow cylinder.

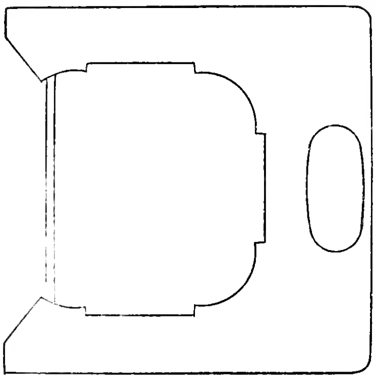


Fig. 3.

No nails or brads are allowable in a stove pattern, the web being so thin and tender as not to receive them; this fact sometimes necessitates the gluing together of long and very thin strips, requiring skill and dexterity on the part of the pattern-maker. Finally, the mere handling of pieces like swollen oven doors, when temporarily off their followboards, composed, as they are, of upwards of one hundred pieces glued one to another, demands a carefulness of manipulation, that in the majority of cases is learned by the workman only by gluing up and repairing many broken patterns after working hours. Through the courtesy of a local stove founder I am enabled to place before you some iron cook's stove patterns, which, in connection with the drawings I have made, will serve to illustrate by that best of all methods, ocular demonstration, how some of the difficulties of the molder are overcome. A piece like Fig. 3 is likely to straighten considerably in cooling; this is prevented by casting a tie across the space *A A*, which is knocked out by the molder when he shakes out his work. A very thin flat plate will get damp and swell when put into the sand; this is provided for by cutting slots $\frac{1}{8}$ inch wide from the body of the pattern (Fig. 4). These slots give room for the excess of wood caused by swelling, prevent buckling, and if all the

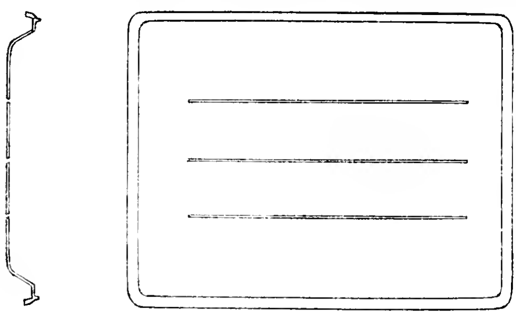


Fig. 4.

space is not taken up the excess of sand can be readily slicked out by the molder. One striking peculiarity of the stove foundry is that there is no core-maker there. To do without his services many an ingenious device has been put in practice: *e. g.*, in the cup of a cook's stove cover you will notice two little projections, one on either side, to form a hold for the lifter: these are made by means of two small punches riveted to the cope side of the cover pattern, which, being

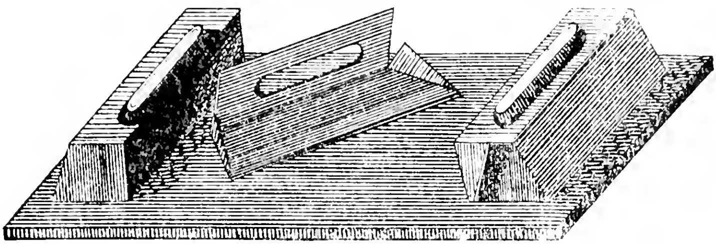
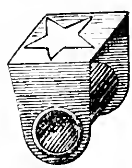


Fig. 5

pushed toward each other by means of the thumb and forefinger of the molder, form two little indentations and are then allowed to return automatically to their original positions. The impressions thus formed, when filled with molten iron, become the projections. The feet of stoves are usually fastened in place by means of "duffs" driven to a taper dovetail, which is molded easily enough by having the side pieces which form the boundaries loose on the main pattern, the molder picking them out of the cope. It is a curious fact that all this can now be cleverly accomplished without coring, or picking out loose pieces from the mold, simply by laying in two pieces of tin of this form (Fig. 5), which after the operation of casting, have become a part of the finished work. Another ingenious device (Fig. 6) causes the holes in door hinges to be made absolutely perfect without coring or drilling, and at the same time makes it possible to have the doors of any certain pattern of stove interchangeable; a result not to be obtained with any show of consecutive surety by means of the old method of drilling involving templates or even jigs. The slotting of door catches, which has been variously effected by filing, milling, or by means of a chill core laid in the mold and driven out by the workmen when the casting was completed, is now accomplished in much the same manner as the holes are left in the door hinges. So perfect a surface does this device (Fig. 7) present that a file in the hands of a careful mechanic cannot improve it.*



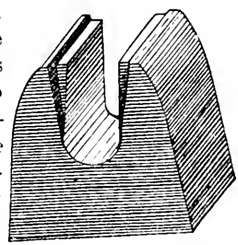


Fig. 6

*It is not meant that the expedients and methods enumerated above are all now in general use, but rather that they are practical, and are being well received by stove founders as they come to see their worth as labor-saving devices. That some of the things mentioned are covered by letters patent is no drawback, their cost being merely nominal when compared with their value in the foundry.

Oven doors are usually lined with tin on account of a superstition that the heat must be reflected in order to obtain the best results in cookery: because of the prevailing fashion of decorating the panels with nickeled or bronze plates this lining has been a source of annoyance, as the medallions have to be easily removable for shipment or for cleaning and polishing. Many schemes have been brought forth to fasten these plates securely by bolting without exposing the nut or burr on the inside of the oven. Some have even gone so far as to tap the holes in the door, which is con-

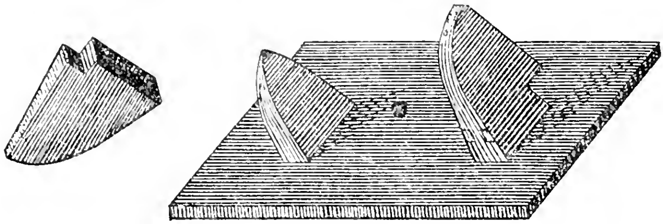


Fig. 7.

sidered no common sin in the eyes of the model stove founder. The desired result is now neatly obtained by casting a square hole in the door a little larger than the nut, having an extension or slot to take the diameter of the bolt: when inside the nut is dropped into an L-shaped recess cast onto the inside of the door, which prevents its turning while being screwed home from the outside. Simply unscrewing a couple of turns and the medallion is easily lifted out for any purpose (Fig. 8).

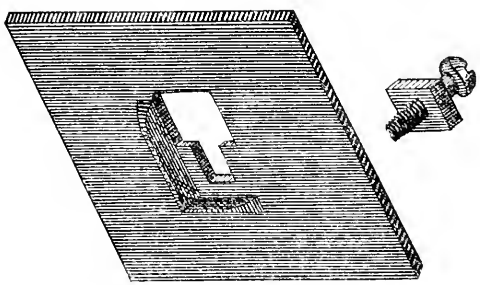


Fig. 8.

The foregoing examples might be multiplied but for the danger of wearying you in the recital.

The stove mounter is a great man in his way, and wrestles with many discouragements. He must take the castings from the shelves and put them together well enough to pass the inspector: one day the iron will incline to be coldshort, and perhaps the next day the mixture will be decidedly redshort. A great disparity in the shrinkage of the plates is the result. A molder may have got in too much water when he wet down his sand heap, in this case the edges of his work are so chilled as to discourage a file or drill, and almost turn down an emery wheel; but no matter, the mounter has to get those castings into stoves, and generally on the piece-work plan. As in all cases of multiplied error, the last segment must atone for all preceding, so many of the minor mistakes in design and construction of stoves finally mass themselves to the mounter's discomfort and vexation. It is not surprising, then, that a great deal of advice comes to the designer from the stove mounter either indirectly or

otherwise, or that he holds the whole guild of designers, pattern-makers, etc., in high disdain.

From a somewhat careful study of this subject one fact seems to be omnipresent, viz.: the necessity for educated designers and mechanical engineers to enter this field and remedy the crudities and errors so patent on every hand : and not alone is this true of cook's stoves, but even more especially of those constructions intended for heating purposes ; and in those designed to utilize the fuel of the future, viz., gases generated from fluids and natural gas, the discussion of which has been purposely omitted, but which is far more interesting than the cook's stove, though perhaps scarcely as important. This paper was prepared with the hope of interesting some members of this Club to take part, either directly, or indirectly by influencing others, in the study and practice of what has been so aptly called Fireside Engineering.

Some members of this society have sons in schools of engineering, or have young men, students and learners employed in their drafting offices; why not impress on such the immense importance of the field open and inviting men of learning and inquiring minds ? Not one book on stove making : so far as I know but three stove designers in the country who are graduates of technical schools, and yet what subjects more alluring than the chemistry of cookery, the phenomena of heat, or the resistance and life of iron under such exceptional conditions of heat and cold ? Even the social problem itself hinges on these things. Are we well fed and comfortably warmed ? How much may be accomplished in order that we may answer this affirmatively with the aid of the common cook's stove, improved and perfected by thought and investigation and experiment.

A GLANCE AT THE ENGINEER'S WORK, PAST AND FUTURE.

AN ADDRESS BEFORE THE ENGINEERS' CLUB OF ST. LOUIS, BY ROBT. MOORE, RETIRING PRESIDENT OF THE CLUB.

[Read December 16, 1885.]

It is a custom now well established in associations such as this for the retiring president to sum up the results of the year's work in the special field of the society's activity, and to note the progress, if any, which has been made. Such a résumé has a use like the daily reckoning of the shipmaster, by which he determines how far he has come and how many miles are yet to be traversed before the completion of his voyage.

Following this time-honored custom, I will ask your attention to a very rapid and incomplete survey of the results of the engineer's work in the past and an equally brief glance at a few of the tasks which lie before him in the future. In doing this I shall, as a definition of the engineer's work, adopt the well-known formula of Telford, which is incorporated into the charter of the Institution of Civil Engineers, of which he was one of the founders and the first President. By this we are told that it is the task of the engineer " to direct the great sources of power in nature for the use and convenience of man." Men of other professions—the lawyer, the merchant, the statesman, the director of great business enterprises—are employed primarily in studying and directing men ; their contests are heated encounters with living foes, in which too

often every unsocial passion is aroused, and their triumphs are purchased by the discomfiture and heart-burnings of other men. But it is the engineer's work to study and direct the forces of nature; his battles are with the elements, and his triumphs are for the benefit of all mankind. In the story of human progress no chapter is more important than that which relates to the victories of the engineer.

Glancing at the additions to this chapter which have been made during the past year, we cannot say that the record of work done in the year 1885 is relatively of very great importance. The financial depression, which for the last four years has prevailed throughout the world, has to a large extent paralyzed the engineer. Even this year, however, which in its first half witnessed the lowest ebb in the business tide for many years, has not been wholly barren of engineering results. A few great works here and there have been completed, and a few no less important have been begun.

Of the former class, that of works completed, we may note in England the completion of the Severn tunnel, four and a half miles in length under the river, by which, at a cost of more than eight millions of dollars, the Great Western Railway gains a more direct access to Wales.

On this continent the greatest event of the year has been the completion of the Canadian Pacific Railway, which binds with an iron highway, wholly on British soil, the waters of the Atlantic and Pacific oceans. But while this has been built on British soil with money furnished chiefly from the mother country, it is an enterprise which has been carried through very largely by citizens of the United States, which have from the first furnished a large number of the officers, a great part of the contractors, and nearly all the engineers, the consulting engineer of bridges being a member of our own club.

Of works wholly American the most noteworthy has been the final and eminently successful explosion of Flood Rock in the East River, at New York, by which nine acres of rock were shattered at a single blast, and an obstacle to commerce which but a few years ago was beyond the resources of the engineer put in the way of easy and complete removal.

Of works recently begun, but not yet completed, mention may be made of the new Tay bridge, built to replace the one of unhappy memory, and also the great bridge over the Frith of Forth, whose enormous spans will eclipse anything yet built in the world; while, on this side of the water, we have the new Croton aqueduct, which, thanks to the power drills and high explosives of very recent times, is to be built of choice as a tunnel throughout nearly its whole length of thirty-three miles. And when the dam of 178 feet in height, which is to be placed at the head of it across the Croton valley, is completed, the whole work will stand easily the greatest of all works of its kind.

Among works in progress mention ought also to be made of the Panama Canal, one of the great undertakings of modern times, by which a continent is to be cut in twain and a highway opened for the commerce of the world; though it ought also to be said that as time advances the doubts of engineers thicken as to whether the project was not undertaken without a due consideration of the difficulties to be overcome. The testimony of competent witnesses seems to show that the problem of con-

trolling the Chagres River, which uncontrolled will render the canal useless, is still very far from solution, and that the data for so doing are not yet all gathered, whilst at the great summit cut, of nearly 300 feet in depth, the amount of water so far encountered is so great as to make it as yet uncertain how much must be taken out, or whether, when taken out, a cut of that magnitude in such materials can ever be maintained. So that while the interests and good wishes of the world are all enlisted for the success of the intrepid builder of the Suez Canal in his new enterprise, it is not yet certain that he may not have to pay the penalty of failure for his rashness in beginning a work of wholly unprecedented kind without first knowing all the facts and submitting them to an exhaustive engineering study.

On the whole we cannot say that the past year has added anything very remarkable to the records of engineering work. While it has not been a year of idleness, there is nothing in it so far as we can now see to mark an epoch or make its record one of any peculiar interest hereafter.

The progress of engineering and the results which it has wrought in the conditions of mankind cannot, however, be properly seen from the records of any single year. To really see what has been accomplished the events of a much longer term must be taken into the account. A single twelve month is, in fact, too short a time to show the real drift and magnitude of any great movement. To see what the engineer has done and is doing for the world we need not, however, to turn the pages backward very far.

Going back no longer than the recollection of living men, the changes which have been wrought by engineering works are so great as to have been wholly incredible if they had been foretold, while the work of the last century amounts to little less than the creation of a new world.

Not to speak of the manifold results which have been wrought by the steam engine, the cylinder press, the power loom, or the telegraph, take as an example of what the engineer's work has done for the world the results which within the narrow scope of two generations have been accomplished by the single agency of the railroad. Consider how it has quickened all the interchanges of life; how it has unlocked the wealth of the continent by giving value to products which before had none; how it has peopled our prairies which without it would hardly have been habitable; how it has made men acquainted with each other; how it has destroyed provincialism, broadened men's minds, deepened their charity and placed all life upon a higher plane. Notwithstanding our diverse origins, and despite the work of civil war, the railroad is making of this nation one people, from the lakes to the gulf, and from ocean to ocean. Without its agency it is not too much to say that the continued union of our States under one government would not have been possible.

In other countries the effect of this new power must inevitably be the same. As men of different nations come by the agency of railroads to know each other better, they will cease to hate each other and become bound together by a thousand ties of mutual interest, so that with each year they will be more and more averse to war. And it is not a bold prophecy to say before many generations George Stephenson's locomotive

will conquer all the armies of Europe and render that turbulent continent as peaceful as our own.

In regard to the future of the engineer's work, it would of course be a waste of time to venture any detailed predictions. For in the time to come, as in the time past, nothing is more certain than that the most sagacious foresight will be outwitted, and that for the most part it will be the unexpected that will happen.

It is quite possible, however, to state some of the tasks which lie yet before us, and to indicate some of the lines on which the engineer must work. It is, for example, altogether safe to say that vast progress yet remains to be made in the utilization of the energy of nature; that the engines now at work will be vastly improved; and that new methods of converting molecular into mechanical motion will be discovered. The steam engine as we now have it is a great miracle-worker to which our indebtedness is beyond computation, but we are not likely to be forever contented with an agency which returns us for use but one-tenth of the energy of the fuel. Could heat be converted at once into electricity on a large scale without the intervention of any intermediate machinery, as can now be done on the small scale by the thermo-electric pile, our steam engines would soon become antiquated and useless. And when we compare the powerful dynamos of to-day with the toy machines of a quarter of a century ago, the search for some new generator of electric energy which shall supersede all other prime movers would seem to be very far from hopeless.

But, counting nothing for any discoveries wholly new, we can with the utmost confidence look forward to such improvements in the machines and methods now in use and to such extensions in the application of knowledge which we now possess as will produce changes almost equal to those we have witnessed already. The mechanical engineer will give us more efficient engines and will distribute power cheaply from central stations to all places and for all uses. Heat will be brought into our dwellings from central stations and be as much a matter of course as water and gas are now. The engineer of roads and bridges will build better roads and safer bridges. The electrical engineer will bring into every household the telephone and the incandescent light. The architect will give us better houses and carry comfort and beauty even into the dwellings of the poor, while the sanitary engineer will see that pure water is put within the reach of all and that the wastes of life are disposed of so as to be productive of good rather than harm. In a word, all the work of the engineer will be performed more efficiently and with less waste.

Thanks to the labor of his predecessors and to the better training which he will receive, the engineer of the future will be more skillful than the engineer of the past or of the present. With no greater native ability or fertility of invention, he will yet have a better command of principles and a wider range of resources, and he will be unworthy of his opportunities if he do not outstrip all his predecessors in unlocking the treasures of nature for "the use and convenience of man."

TABLES FOR CALCULATION OF END AREAS.

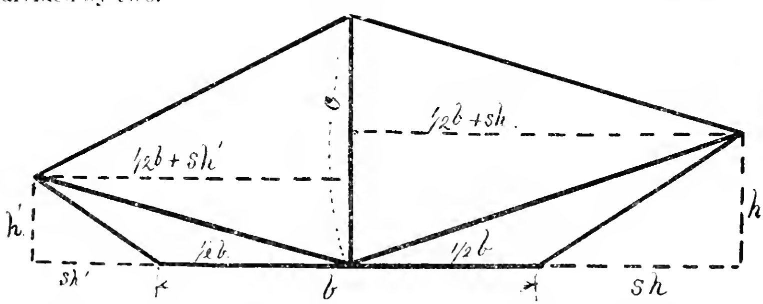
By W. W. Redfield, Member of the Engineers' Club of Minnesota.
[Read February 12, 1886.]

In the computation of the quantities of excavation or embankment on railroad or other similar work, there are two parts generally to the operation. First is the computing of the areas at the places where cross-sections of the work are taken; and secondly is the computing from these areas of the volumes embraced between any two consecutive areas. The prismoidal formula is absolutely accurate for this purpose, but for many reasons not the one generally used. Most frequently the method of averaging end areas is employed, as being simple, and in certain cases considered accurate enough. Other methods are also used. This paper, however, only proposes to deal with the first part of the calculation; that is to say, with the method of finding the end areas. In some cross-section field-books, the distances out of the side or slope stakes are recorded, and in others, not. This record of distances out is, in itself, a good thing, for many reasons, but for purposes of calculating the end areas by my tables not at all necessary.

When time in the field is valuable, it is very often a great saving to have only to record the left, centre and right cut, or fill at each station. My tables are based on the formula very generally used:

$$\frac{c\,(d + d') + \frac{1}{2}\,b\,(h + h')}{2};$$

which is in words: the centre height into the sum of the distances out plus half the road-bed width into the sum of the side heights, and all divided by two.



Now I start with the same formula: c is the centre cut or fill, h and h' the side cuts or fills, b the width of road-bed, s the ratio of base of slope to height of slope—generally $1\frac{1}{2}$, sometimes 1, and in rock frequently $\frac{3}{4}$: d and d' are the horizontal distances to h and h' respectively.

But instead of d and d', we may write their equivalents:

$$\left.\begin{aligned} d &= \tfrac{1}{2}\,b + sh \\ \text{and } d' &= \tfrac{1}{2}\,b + sh' \end{aligned}\right\}$$

and substituting these values for d and d', and dividing the area in the figure or diagram into four triangles in the customary manner, we have for the entire area as follows:

$$A = \tfrac{1}{2}\,(\tfrac{1}{2}\,b + sh)\,c + \tfrac{1}{2}\,(\tfrac{1}{2}\,b + sh')\,c + \tfrac{1}{2}\,(h \times \tfrac{1}{2}\,b) + \tfrac{1}{2}\,(h' \times \tfrac{1}{2}\,b) = \tfrac{1}{4}\,bc + \tfrac{1}{4}\,bc + \tfrac{1}{2}\,c.s.\,(h + h') + \tfrac{1}{4}\,b\,(h + h')$$

$$\text{or } A = \tfrac{1}{2}\,bc + (h + h')\,[\tfrac{1}{2}\,s.c + \tfrac{1}{4}\,b].$$

Now, on inspection of the formula as arranged in this manner, it will be

seen to consist of two parts, added together. The first part is $\frac{1}{2}\,bc$, which varies in direct proportion to any variation of c. (We assume a constant value for b and for s in making out any table.) The second part is the product of two factors $(h + h')$ and $(\frac{1}{2}\,s.\,c + \frac{1}{4}\,b)$; the last factor varies as c, but with $\frac{1}{4}\,b$ added each time. The tables are in three columns each; each different road-bed width b for each different value of s requiring a separate table. In the first column are placed the successive values of centre-heights from zero as far as is desirable to construct any table: in the second column are placed values of $\frac{1}{2}\,b\,c$; and in the third column are placed values of $\frac{1}{2}\,s.\,c + \frac{1}{4}\,b$. The sum of the second and third columns would make the area required for any given centre cut or fill in the first column, in case $h + h' = 1$. Hence the manner of using the table is obvious:

Let us imagine one or two examples, from samples of two different tables:

TABLES FOR CALCULATING END AREAS.

(Copyrighted April 18th, 1879, by W. W. Redfield.)

—Base 14 feet. Slope $1\frac{1}{2}$ to 1.—			—Base, 14 feet. Slope, 1 to 1.—		
Centre height.	$\frac{1}{2}\,bc.$	$\frac{3}{4}\,c + \frac{1}{4}\,b.$	Centre height.	$\frac{1}{2}\,bc.$	$c + \frac{1}{4}\,b.$
0.0	0.0	3.5	0.0	0.0	3.5
.1	.7	3.575	.1	.7	3.55
.2	1.4	3.65	.2	1.4	3.6
.3	2.1	3.725	.3	2.1	3.65
.4	2.8	3.8	.4	2.8	3.7
.5	3.5	3.875	.5	3.5	3.75
.6	4.2	3.95	.6	4.2	3.8
.7	4.9	4.025	.7	4.9	3.85
.8	5.6	4.1	.8	5.6	3.9
.9	6.3	4.175	.9	6.3	3.95
1.0	7.0	4.25	1.0	7.0	4.0
.1	7.7	4.325	.1	7.7	4.05
.2	8.4	4.4	.2	8.4	4.1
.3	9.1	4.475	.3	9.1	4.15
.4	9.8	4.55	.4	9.8	4.2
.5	10.5	4.625	.5	10.5	4.25
.6	11.2	4.7	.6	11.2	4.3
.7	11.9	4.775	.7	11.9	4.3
.8	12.6	4.85	.8	12.6	4.4
.9	13.3	4.925	.9	13.3	4.45
2.0	14.0	5.0	2.0	14.0	4.5
.1	14.7	5.075	.1	14.7	4.55
.2	15.4	5.15	.2	15.4	4.6
.3	16.1	5.225	.3	16.1	4.65
.4	16.8	5.3	.4	16.8	4.7
.5	17.5	5.375	.5	17.5	4.75
.6	18.2	5.45	.6	18.2	4.8
.7	18.9	5.525	.7	18.9	4.85
.8	19.6	5.6	.8	19.6	4.9
.9	20.3	5.675	.9	20.3	4.95
3.0	21.0	5.75	3.0	21.0	5.0
.1	21.7	5.825	.1	21.7	5.05
.2	22.4	5.9	.2	22.4	5.1
.3	23.1	5.975	.3	23.1	5.15
.4	23.8	6.05	.4	23.8	5.2
.5	24.5	6.125	.5	24.5	5.25
.6	25.2	6.2	.6	25.2	5.3
.7	25.9	6.275	.7	25.9	5.35
.8	26.6	6.35	.8	26.6	5.4
.9	27.3	6.425	.9	27.3	5.45
4.0	28.0	6.5	4.0	28.0	5.5

General formula is, $A = \frac{1}{2}\,bc + (h + h')\,(\frac{1}{4}\,b + \frac{1}{2}\,sc)$.

Road-bed = 14 feet; slope = $1\frac{1}{2}$; centre = 3.8 feet; left = 2.4 feet; right = 0.8 feet.

Required the area: Look in the first column of centre-heights, find 3.8. Opposite this in the third column is 6.35. The sum of the side heights is $2.4 + 0.8 = 3.2$ (performed mentally).

Then, $6.35 \times 3.2 = 20.32$; and $20.32 + 26.6$ (the number in second column opposite the same 3.8) $= 46.92$ square feet = area required.

Again: Road-bed = 14 feet; slope = 1; centre = 2.0; left = 3.7; right = 1.2; 4.5 (number in third column) $\times$ 4.9 (sum of side heights) = 22.05; $22.05 + 14$ (number in second column) = 36.05 square feet = area required.

Hence it will be seen that only two operations are required. The writer has himself used these tables in actual practice in computing areas on several miles of railroad work, and prefers their use for rapid progress in taking out areas. He uses them as follows: The Division Engineer (on some roads this position and that of Resident Engineer are reversed) has the proper table open before him on his left. He ascertains from his note-book a centre height, and finds the third column number for said centre height, calls off said third column number; he and his rodman set that number down on their figuring paper; he next calls off the sum of the side-heights, having added the same mentally. Both calculators multiply and check with one another; then the second column number is called off and added to the product, and then checked, and *that* area is out; all taking less time than would be imagined without trying it.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

FEBRUARY 17, 1886 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:40 P. M., President George L. Vose in the chair ; thirty-four Members and eight visitors present.

The record of the last meeting was read and approved.

The following persons were proposed for membership : George Bowers, by J. Francis, F. P. Spalding ; Walter S. Coffin, by F. P. Stearns, E. C. Clarke ; George C. Currier, by E. W. Howe, S. E. Tinkham ; Willis H. Hall, by M. T. Cook, E. D. Leavitt, Jr. ; Samuel L. Minot, by G. R. Hardy, E. W. Howe ; Fred. B. Sherburne, by F. P. Stearns, F. P. Spalding ; J. A. Tilden, by E. H. Gowing, W. T. Pierce.

The Committee appointed to prepare a memorial on the death of Mr. H. M. Wightman presented the following :

HENRY MORSE WIGHTMAN.

Member Boston Society Civil Engineers.

Died April 3, 1885.

Henry M. Wightman was born in Boston, January 5, 1840. He was educated in the public schools of the city, and graduated from its English High School in 1857. Soon after graduating he was appointed rodman in the City Engineer's department, and from that position he rose by successive stages to that of its chief, having been elected City Engineer, March 18, 1880.

His engineering experience, covering twenty-eight years of practice, gave him a high rank in the profession. It was almost altogether gained while connected with the above-mentioned department, but it covered a great variety of work, some of which presented more than ordinary difficulties to overcome, and some of which ranks high in the scale of importance.

In the earlier years his work was of that miscellaneous character which usually comes to the hands of a subordinate in the office of a City Engineer.

In 1863 he was placed in charge of the preliminary surveys for a new distributing reservoir, proposed to be built in the vicinity of Chestnut Hill, in extension of the system of water supply from Lake Cochituate. Three sites were reported upon.

In 1864 he acted as engineer for the Back Bay Commission, and in that capacity made surveys and plans for laying out the Back Bay district.

In 1865 he was placed at the head of a party to make accurate location-surveys and the plans for building the Chestnut Hill reservoir, an appropriation for building it having been made by the City Council the previous year. In the spring of 1866, he was appointed Resident Engineer in charge of its construction, and although appointed Assistant City Engineer in May, 1870, performed the duties of the former office till the fall of 1870, at which time the work of construction was so nearly finished that the larger of the two compartments was filled with water and placed in service.

The Chestnut Hill reservoir is a structure of more than local reputation; it is one of the largest and best built distributing reservoirs in the country, and the experience that Mr. Wightman gained while in charge of its construction was of the highest value to him in after years.

He occupied the position of Assistant City Engineer till the spring of 1880, when he was elected City Engineer, which office he held till the time of his death.

The more important works done under his direction as City Engineer were: the completion of the Main Drainage Works; the construction of Basin No. 4, for an additional supply of water; the rebuilding of Warren Bridge; the building of the bridge over the Boston & Albany Railroad on the line of Broadway Extension; the preparation of plans for a new bridge from Boston to Cambridge; and the construction of the Back Bay Park. This last work involved some interesting hydraulic problems and the construction of a number of important bridges, the Boylston Street skew-arch of sixty feet span presenting some novel features.

On March 21, 1885, Mr. Wightman started for North Carolina on some private business. On his way back he was taken ill with pneumonia, and upon his arrival at home, March 27, was obliged to take to his bed.

On Friday, April 3, when he was thought to be improving, he became suddenly delirious, and continued in that state till 8:45 that evening, when he died.

Mr. Wightman was a man of sound judgment and an excellent manager of engineering work, being prompt in his decisions and firm in enforcing them. While fully appreciating the responsibility attaching to his work, he rarely allowed it to worry him.

When things did not please him, he was open in his criticism of men and methods, but he was true and warm to his friends.

He became a Member of the Boston Society of Civil Engineers June 8, 1874; he was also a member of the American Society of Civil Engineers.

[Signed] JOSEPH P. DAVIS,
CLEMENS HERSCHEL,
EDWARD W. HOWE.

A letter was read by the Secretary from Major C. W. Raymond, submitting his resignation as a Member of this Society in consequence of his transfer to New Orleans.

On motion, it was voted: That Mr. H. Manley and the President be appointed a committee to arrange for the annual dinner.

On motion, it was voted: That a committee be appointed by the chair to present a list of candidates for officers of the Society for the ensuing year, and that the committee be instructed to present three names for each office.

The committee as appointed consists of Messrs. F. Brooks, Swain and Folsom.

On motion, it was voted: That an appropriation of five dollars be made for the Society's subscription to *Railroad Gazette* for the year 1886.

Mr. H. F. Walling read a paper on State Topographical Surveying.

Mr. H. Bissell addressed the Society on certain processes of Wood Preserving.

[*Adjourned.*] H. L. EATON, Secretary.

MARCH 3, 1886:—A special meeting of the Boston Society of Civil Engineers was held and called to order at 7:55 P. M. President George L. Vose in the chair; seventeen Members, one visitor present.

Mr. Chas. H. Swan, Chairman of the Committee on Weights and Measures, presented a report from that Committee.

Mr. E. W. Howe moved that the Report of the Committee on Weights and Measures be accepted and printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. This motion was declared to be adopted. Mr. Albert H. Howland doubted the vote, and the yeas and nays were ordered. The motion was carried: yeas eleven, nays one.

Mr. Fred Brooks read a paper on Metric and Old Units with reference to convenience.

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL MEETING.

MARCH 17, 1886:—The annual meeting of the Boston Society of Civil Engineers was held at Young's Hotel, Boston, and called to order at 4:50 P. M., Vice-President L. Frederick Rice in the chair. Fifty-nine Members, eight visitors, present.

The records of the regular meeting February 17, and the special meeting March 3, were read and approved.

Messrs. G. Bowers, W. S. Coffin, G. C. Currier, W. H. Hall, S. L. Minot, F. B. Sherburne, J. A. Tilden were elected Members of this Society.

The following persons were proposed for membership: F. C. Coffin, by M. M. Tidd, E. A. W. Hammatt; G. E. Evans, by James Francis, A. W. Hunking; G. A. Nelson, by J. R. Freeman, R. A. Hale; F. B. Knapp, by W. S. Chaplin, G. L. Vose.

The Treasurer presented his annual report, properly approved by the Auditor.

The following recommendations were submitted by the Government:

That a vote of thanks be extended the General Manager of the Boston & Albany Railroad for the use of the rooms occupied by this Society.

That a Special Committee on Library be appointed; this Committee to consist of five persons, of which the Librarian and Secretary shall be members, ex-officio.

That the cost of the book-cases in the Society's room at the B. & A. R. R. station, being in the nature of an investment, be paid from the permanent fund instead of the current fund.

That the salary of the Secretary be increased.

That the list of Corresponding Members be dropped, and Mr. C. H. Haswell be made an Honorary Member of this Society.

That an assessment of $6 be levied on resident members of this Society.

That Article XIV. of the Constitution be so amended that the cost of the JOURNAL from the date of admission to the Society to the date of the next assessment shall be added to the admission fee.

That Article XV. of the Constitution be amended to increase the annual fees payable by non-resident members to $4.

The Annual Report of the Government was read by the Vice-President.

On motion, it was voted: That the Annual Reports of the Treasurer and Government be accepted and printed with the proceedings of the Society.

On motion of Mr. H. A. Carson it was voted: That an assessment of $6 be levied on resident members of the Society.

On motion, it was voted: That the recommendations submitted by the Government be laid on the table until the next meeting, and printed in the notices of that meeting.

The Committee on Furnishing Room presented a verbal report, with a request for further time, which was granted.

The Committee appointed to present a list of candidates for officers of the Society for the ensuing year presented the following report:

For President—W. H. Bradley, C. Herschel, G. L. Vose.

For Vice-President—E. C. Clarke, D. Fitz Gerald, L. F. Rice.

For Secretary—H. L. Eaton, F. P. Stearns, S. E. Tinkham.

For Treasurer—H. A. Carson, T. W. Davis, H. Manley.

For Librarian—F. W. Hodgdon, W. Shepard, H. D. Woods.

On motion, it was voted: That the officers be balloted for on separate ballots.

That a committee of three be appointed by the Chair to receive, sort and count ballots for President and Librarian; that a committee of three be appointed by the Chair to receive, sort and count ballots for Vice-President, Secretary and Treasurer.

Messrs. M. M. Tidd, Albert H. Howland and C. W. Folsom were appointed a committee on election of President and Librarian, and Messrs. Adams, Carr and Worcester on election of Vice-President, Secretary and Treasurer.

The Society then proceeded to ballot for officers, with the following result:

President, G. L. Vose; *Vice-President*, L. F. Rice; *Secretary*, H. L. Eaton; *Treasurer*, H. Manley; *Librarian*, H. D. Woods.

Mr. F. P. Stearns was appointed Auditor by vote.

On motion it was voted: That the election of special committees be laid upon the table until the next meeting.

The Secretary read a paper from Mr. G. E. Evans, City Engineer of Lowell, Mass., on the Beacon Street Reservoir, Lowell Water-Works, and the accident which happened there in the fall of 1885.

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL DINNER.

MARCH 17, 1886:—The fourth annual dinner of the Boston Society of Civil Engineers was held at Young's Hotel, at 6 o'clock P. M., Vice-President L. Frederick Rice in the chair, sixty-two Members present.

There were present, as guests of the Society, William T. Sedgewick, Edward S. Morse, James T. Furber and James E. Howard.

Mr. Thomas Doane alluded to the earlier days in the Society's history, and gave short sketches of the lives of Messrs. Samuel Nott, W. S. Whitwell, Loammi Baldwin, G. S. Baldwin, James Hayward, Ezra Lincoln, Alexander Wadsworth, William T. Parrott, Robert Eddy, Charles S. Storrow and others.

William T. Sedgewick, Professor of Biology, Massachusetts Institute of Technology, referred to the uses of applied science, and the usefulness of pure scientific work; its connection with civil engineering, the claims of pure science and the necessity of placing the teaching of pure science in a foremost position in our educational institutions.

Winfield S. Chaplin, Professor of Civil Engineering, Lawrence Scientific School, referred to the progress made in civil engineering in the last thirty years, the increase in the number of scientific schools and the prominent position taken by American civil engineers.

Mr. A. W. Locke, Manager of the Troy & Greenfield Railroad and Hoosac Tunnel, defined the policy of the State in the management of the Hoosac Tunnel property, and stated that the cost per ton per mile of freight transported was 7.3 mills.

Reference was also made to the connection of civil engineers with railroad transportation, the improvements made in rolling stock, the necessity of providing a permanent road-bed and the necessity of placing the control of railroads in the hands of trained civil engineers.

Mr. L. F. Rice alluded to the prominent place occupied by the Rensselaer Polytechnic Institute among scientific schools and to the large number of its graduates who hold high positions and are connected with the management of railroads and public works.

C. D. Bray, Professor of Civil and Mechanical Engineering, Tufts College, referred to the common interests existing between professors in scientific schools and practicing civil engineers.

Professor Edward S. Morse, Director of Peabody Academy of Science, Salem, Mass., alluded to the great results which have followed from the examinations made by workers in applied science and the scientific attainments of the Japanese in adapting the means at their command to the end desired in their buildings and public works.

Mr. Henry F. Walling entertained the company with a poem on prophetic engineering, entitled the "Magic Clock."

Mr. James T. Furber gave some personal recollections of some of the civil engineers connected with the early history of the Boston & Maine Railroad. He also alluded to the great importance of a training in civil engineering to a railroad manager, and the necessity of constructing the road-bed in the most substantial manner, and heavy enough to carry the heaviest rolling stock.

Mr. James E. Howard, engineer in charge of the testing machine at the Watertown Arsenal, stated what had been accomplished in testing materials, and described some experiments on riveted joints, brick piers and wrought-iron axles.

Note.—Mr. J. E. Howard's remarks will be printed in full in the next issue of he JOURNAL. H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

MARCH 3, 1886:—Club met at Mercantile Library at 8:15 P. M., President McMath in the chair and eighteen members present. Minutes of last meeting read and approved.

The applications for membership of Mr. William T. Angell, of St. Louis, proposed by J. H. Kinealey and William H. Bryan, and Mr. William D. MacQuesten, proposed by William H. Bryan and N. W. Perkins, Jr., were referred to the Executive Committee.

The special Committee on Complimentary Lunch to Colonel Flad reported and asked for instructions. The committee was authorized to complete arrangements and issue notices.

The Secretary announced that the Club had received a copy of the Report of the Massachusetts Drainage Commission, the donation of Mr. Eliot C. Clarke, Chief Engineer.

Mr. Robert E. McMath read a paper on "The Future Drainage of St. Louis."

A general discussion followed.

[*Adjourned.*] THOMAS D. MILLER, Secretary.

ENGINEERS' CLUB OF MINNESOTA.

MARCH 12, 1886:—Regular meeting: President D. P. Waters in the chair. Present, Messrs. W. W. Redfield, C. Sprague, E. T. Abbott, James Waters, G. W. Sublette, A. C. Libby, Wm. De La Barre, J. H. Barr, W. S. Pardee. Previous records were read and approved.

Mr. E. T. Abbott reported the reception of additional circulars from the Executive Board of the Temporary Civil Engineers' Committee on National Public Works.

The President addressed the Club, setting forth the importance of the coming Cleveland meeting, and urging the Members to take an active and effective part in furthering the interests of the convention.

On motion, it was resolved that it is the sense of the Club to stand by the members of Committee on National Public Works and give them prompt support.

On motion, Mr. Abbott was appointed delegate to the convention called to be held at Cleveland, March 31, in place of Mr. Platt B. Walker, resigned.

On motion, Messrs. A. C. Libby and E. T. Abbott were appointed a committee to confer with the directors of the new public library at Minneapolis, with a view to providing in said library a full department of engineering works.

Mr. Abbott made a report on the matter of new quarters for the Club, and the furniture from the old quarters was placed in the care of Mr. De La Barre.

Mr. John Lamb was elected Member, and Mr. J. M. Hazen was presented for membership, vouched for by W. S. Pardee and W. W. Redfield.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. | May, 1886. | No. 7.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

COMPARATIVE SIZE OF METRIC AND OLD UNITS, WITH REFERENCE TO CONVENIENCE.

ERRATUM.—The last line of the table on page 226 should read 1 pound per cu. foot and 16. kilos per cu. meter : *not* .16.

absorbed by the memory. Three leading units, of length, weight and bulk, are made conspicuous each as nine-tenths of its metric analogue : and the true relations among the old units are adhered to as far as practicable in the approximate equivalents, so that one equivalent may be associated in the mind with another. For example, the quart being 0.9 of a cubic decimeter. the cubic foot, or 30 quarts, is 30×0.9, or 27 cubic decimeters; again, the ounce, or weight of $\frac{1}{1000}$ cubic foot of water, is the weight of 27 cubic centimeters of water, or 27 grams. The approximations that are grouped together generally contain the same percentage of inaccuracy. Values sufficiently accurate for business purposes are added in parentheses.

I desire to supplement this table by a few very simple thoughts and numerous illustrative examples as to the convenience of substituting the metric for the old units.

A real objection to any change of standards of weights and measures is the annoyance of the process of transition ; but as most of the opponents as well as the advocates of the metric system declare that some change ought to be made from the existing irregularity of weights and measures, it appears that the annoyance of a transition is unavoidable. The question is : Of what particular change is the annoyance to be preferred? Argument to show that the introduction of the metric system is the change to be preferred has been addressed to the members of this Society and others heretofore ; and little argument is now wanted to show engineers the superiority of the metric system, as little is wanted to show them the superiority of railway over mule transportation. Some conservative men will resist

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COMPARATIVE SIZE OF METRIC AND OLD UNITS, WITH REFERENCE TO CONVENIENCE.

BY FRED BROOKS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read March 3, 1885.]

The most useful thing I have to offer to the Society is a table of equivalents, which I will present to begin with so as to make sure of it. (See the next page.) It shows the comparative size of the principal metric and old units, arranged so that approximate equivalents may easily be absorbed by the memory. Three leading units, of length, weight and bulk, are made conspicuous each as nine-tenths of its metric analogue : and the true relations among the old units are adhered to as far as practicable in the approximate equivalents, so that one equivalent may be associated in the mind with another. For example, the quart being 0.9 of a cubic decimeter, the cubic foot, or 30 quarts, is 30×0.9, or 27 cubic decimeters; again, the ounce, or weight of $\frac{1}{1000}$ cubic foot of water, is the weight of 27 cubic centimeters of water, or 27 grams. The approximations that are grouped together generally contain the same percentage of inaccuracy. Values sufficiently accurate for business purposes are added in parentheses.

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APPROXIMATE EQUIVALENTS.

LENGTH.

1 inch	and	2½ centimeters	(2.54)
1 foot	"	0.3 of meter...	(.3048)
1 YARD	"	0.9 " METER.	(.9144)
1 rod	"	5. meters.....	(5.029)
1 chain	"	20. "	(20.117)
1 furlong	"	200. "	(201.17)
1 mile	"	1600. "	(1609.3)

AREA.

1 sq. inch	and	6¼ sq. centimeters..	(6.451)
1 sq. foot	"	0.09 of sq. meter.....	(.0929)
1 sq. yard	"	0.81 " " "	(.8361)
1 sq. rod	"	25. sq. meters.......	(25.29)
1 rood	"	1000. " "	(1011.7)
1 acre	"	0.4 of hektar........	(.4047)
1 sq. mile	"	256. hektars..........	(258.99)

BULK.

1 cu. inch	and	15⅝ cu. centimeters.	(16.387)
1 cu. foot	"	0.027 of cu. meter...	(.028316)
1 cu. yard	"	0.729 " " " ...	(.7645)
100 cu. feet	"	2.7 cu. meters.....	(2.8316)
(The unit of ship's measurement for register.)			
1 M board meas.	and	2¼ cu. meters.....	(2.36)
1 cord	"	3.6 " "	(3.624)
1 U. S. liq. pint	"	0.45 of liter...... .	(.473)
1 " " " QUART	"	0.9 " LITER......	(.946)
1 " " " gallon	"	3.6 liters..........	(3.785)
1 peck	"	9. "	(U. S. 8.81; Br. 9.08)
1 bushel	"	36. "	(U. S. 35.24; Br. 36.35)
1 ton of ship's displacement	"	1 cu. meter.	

WEIGHT.

1 grain	and	.06¼ of gram	(.0648)
1 troy ounce	"	30. grams..	(31.103)
1 avoir. "	"	27. grams..	(28.35)
1 pound	and	0.45 of kilo.....	(.4536)
60 lbs. (wheat bu.)	"	27. kilos......	(27.216)
80 lbs. (coal bu.)	"	36. "	(36.287)
1 cental	"	45. "	(45.36)
112 lbs. (cwt.)	"	50. "	(50.8)
1 NET TON	"	0.9 METRIC TON	(.9072)
1 gross ton	"	1. "	(1.016)

COMBINATIONS.

1 foot-ton (net)	and	0.27 of (metric) ton-meter.....	(.2765)	WEIGHT AND LENGTH.
1 foot-pound	"	0.13½ " kilogrameter..........	(.13825)	
1 pound per running yard	"	½ kilo per running meter......	(.4961)	WEIGHT PER LENGTH.
1 " " " foot	"	1½ kilos " " "	(1.4882)	
1 pound per sq. foot	"	5. kilos per square meter.......	(4.883)	WEIGHT PER AREA.
(About 1 atmosphere) 1 net ton " " "	"	1 kilo per sq. centimeter.......	(0.9765)	
(About 1 atmosphere) 15 lbs " " inch	"	1 " " " "	(1.0545)	
1 pound " " "	"	0.07 " " " "	(.07031)	
1 net ton " " "	"	0.14 metric ton per sq. centimeter	(.14062)	
1 pound per cu. foot	"	16 kilos per cu. meter.........	(16.019)	WEIGHT PER BULK.

any change of standards as long as they live, and they occasionally allege reasons for their resistance. A man does not like to acknowledge that he is too inert to favor a great public improvement; he probably believes and naturally prefers to say that he has thoughtfully examined the subject, and finds this or that fatal objection to the proposed improvement. It is amusing to notice how inconsistent with one another are some of the objections alleged against the introduction of the metric system. One engineer thinks the yard and inch can never be superseded by the meter, because it is convenient that bar iron has as many square inches of cross-section as it weighs pounds per yard, while another engineer thinks the yard and inch are to be abandoned, and the foot is to prevail, and therefore he opposes the meter. It is objected, on the one hand, that to take an ideal length of one ten-millionth of the earth's quadrant as the basis of weights and measures, and to abandon all customary metrological units, is too much to be attempted; and, on the other hand, that the metric reform does not go far enough, but that the base of arithmetical notation ought to be changed, and our Arabic system of tens, hundreds, and thousands abandoned. One man declares that the natural way to divide things is by successive bisections into halves, quarters, etc., and he objects to any decimal subdivision of weights and measures; a second man favors the metric units with their decimal subdivision, but finds fault with the length and derivation of the metric names, and proposes to substitute others, calling the decimeter a "*hand*," for example, and the kilo a *bi-pound* or "*bip*:" a third man says the objection to the metric system is that it takes novel magnitudes for its unit-bases, and what he proposes is to decimalize old units, and to adopt the names deci-foot, milli-foot, and centi-milli-foot, similar to metric names. The word *mil* is already used in English writings to signify one thousandth of an inch.

Leaving these gentlemen to convince each other as best they can of the errors of their respective opinions, I merely remark as a fact that the decimal metric system of weights and measures is evidently coming into use. In pretty much every country in Christendom changes have been made during the last hundred years for the purpose of introducing decimal systems of coinage, weights or measures in place of former irregularity. The movement is still going on, and we may as well prepare our minds for it as for death or for taxation. Let us consider what decimalization amounts to in practice.

1. The successive sub-units that are used in reckoning are limited to such as are in a tenfold ratio to one another, but *an abundant variety of sizes of implements are used in actual dealings under decimal systems*, whether based on the meter or on anything else.

For instance, in this country our dollar is one-tenth of an eagle, and we have a silver coin of five-tenths of a dollar. We always regard it as half of a unit; if we inquire the price of an article we shall never be told that it is, let us say, seven half dollars, as if this coin were a unit: we may pay seven half-dollar coins for the article, but we think of it as three and one-half dollars expense; and nothing in the transaction need prevent us from boasting that our country has a decimal monetary system. Now, reverse the picture. In England, a florin is one-tenth of the

pound sterling, and they have a silver coin which is five-tenths of the florin; but they don't think of it as a half-florin, they call it a shilling; they don't name a price of three florins and a half, they say seven shillings. Their money is not decimal, as everybody knows. It might be made decimal.

For another instance, one thousandth part of the metric ton on the continent of Europe is the principal commercial weight, called the kilo. A metallic weight of half a thousandth of a ton, or a half-kilo, has, among others, been found very useful in shops. That is decimal just so long as it is treated as $\frac{5}{10}$ of the unit. On the contrary, when, as in Massachusetts, half a thousandth of a ton is a unit, called a pound, and the thousandth part of the ton is not a unit at all, but is two pounds, it is not decimal reckoning. It may be a step toward decimal reckoning, and away from some greater and more ancient irregularity, as the use of the half-kilo as a unit under some name equivalent to the English word pound has been a step toward the introduction of the complete metric system in several European countries. This step was generally taken by a former generation when the metric system was so little introduced as to appear experimental, and when but moderate facilities existed for the dissemination of information among the people, so that a radical change did not appear feasible.

For a third instance, the Gunter chain, used by our grandfathers and still used in many places, is a decimal measure; it is $\frac{1}{10}$ of a furlong, divided into 100 links, and 10 square chains make an acre. Very good. Suppose we make a pole 25 links in length; if we measure off a square with it, that square will contain 625 square links, and be .0625 of a square chain. That is decimal just so long as it is treated decimally as a fraction of the unit, the chain, or as a multiple of the sub-unit, the link. Now make the contrary supposition; we call that pole a unit, measure distances with it, and record them as 2 poles and 5 links, or 3 poles and 8 links, etc.; and we call the square pole a *perch*, use that also as a unit and designate areas as 1 acre and 25 perches, or 2 acres and 30 perches, and the like. Whatever else it may be, this is not a decimal system.

For another instance, most of us use decimal subdivision of the foot and 100 foot tapes, chains, etc., on a certain class of our work. Here is one joint of my leveling-staff, a piece of wood 6 feet long, the feet conspicuously marked 1, 2, 3, etc., and decimally subdivided. If I measure distances with that, regarding it as 6 units, and counting 6, 12, 18, 24 feet, etc., that (be it wise or foolish) is decimal foot measurement; and if I measure a cube having the length of that staff on one side and figure its contents as 216 cubic feet, that is decimal foot reckoning. If, on the contrary, I measure distances counting 1 fathom, 2 fathoms, etc., and perhaps reaching such a result as 3 fathoms and 2 feet, or if I measure a cube having the length of that staff on one side and reckon it as one cubic fathom, I am not adhering to a decimal foot system.

Again, in Texas there are in general use by surveyors to-day chains a little shorter than Gunter's, being 20 *varas* long, with 5 links to a *vara*. If these are always treated as 20 varas and 0.2 of a vara, it is just as compatible with a decimal system based on the vara as a unit, as our use of the 20-dollar gold piece or the 2-dollar greenback is compatible with a

decimal monetary system. Similarly the use of a 20 meter chain or a half-meter rule is just as compatible with the decimal character of the metric system as the use of a 2-foot rule or a 50-foot chain would be with a decimal foot system if properly marked and used. My metric leveling-staff is 4 meters long, and might be 5 meters or 3 meters if I chose. In fact, pretty much any size of implement may be used, *provided* it is used as a multiple and not as a sub-unit.

2. The second point upon which I wish to dwell is the very obvious fact that the adoption of a decimal system, whether based on the meter or on anything else, limits us in reckoning to units that are in a tenfold ratio to one another, and *abolishes reckoning by units of any such magnitudes as several of our ancient customary units.*

Any establishing of standards, such as is now being carried out in a great many kinds of business, means a restriction upon freedom of choice and a forbidding of odd sizes. The adoption of standard time in 1883 meant that different localities and railroads must give up their peculiar time-reckonings, and that all who adopted it throughout the United States of America should be limited to the times of only four meridians separated by intervals of an hour. The adoption of a standard railroad gauge of 4 feet 8½ inches means the abandonment of 6 feet or 5 feet gauges, etc. It is similar with standard units of measure. If any man wants to reckon by two units, one of which is twice, or thrice, or four, six, or eight times as large as the other, if he wants to reckon, in feet, the dimensions of the place where his iron bars are to go, and at the same time wants to reckon the weight of the bars by the running yard and their cross-section in inches, then a decimal system on any basis is just what he doesn't want. There have come into use in the past the greatest variety of units of measurement owing to the different requirements of men, their capricious tastes, negligence and possibly their dishonesty, so that pretty much every size from small to great has been made a unit by somebody. Scarcely one of these units has a magnitude which is more convenient than some other considerably different magnitude would be for the same purpose; one is used rather than the other merely from custom generally; and it will be a positive benefit to get rid of superfluous units and be restricted to a moderate number of standard units of reckoning decimally related. The feasibility of our dispensing with those to which we have long been accustomed may be better appreciated if we recall the way in which several such units have been disappearing within our own knowledge.

Let us illustrate first with money. On February 22, 1821, Hon. John Quincy Adams, then Secretary of State, made a report to the House of Representatives on weights and measures, to which he gave much study and attached great importance. After referring to the United States having adopted as its dollar or unit the Spanish piece of eight, as it was called, meaning the piece of eight "bits" (to use an American expression for the eighth of a dollar), Mr. Adams said: * * "Go to New York and offer in payment the Spanish coin, the unit of the Spanish piece of eight, and the shop or market-man will take it for a shilling." And again: "For all the transactions of retail trade, the eighth and sixteenth of a dollar are among the most useful and convenient of our coins: and although we have never coined them ourselves, we should have felt the

want of them, if they had not been supplied to us from the coinage of Spain." It looks differently in 1886. We don't reckon in shillings, bits or picayunes; don't coin them; don't use the old Mexican coins, and don't feel the want of them. Our units are of very different magnitude. Similarly future generations will use a unit of capacity very different in magnitude from our gallon.*

For another illustration, take up the morning newspaper and look at the reports of the London grain market. Quantities of grain are stated in *quarters*, and prices are per *quarter*. The quarter is a measure that was included in the arithmetics our grandparents studied; but we know nothing about it, yet manage to shift after a fashion with a grain measure of very different magnitude. Likewise our grandchildren may contrive to do business without any measure approaching in magnitude the very numerous *bushels* which now afflict the United States and Canada.

Another unit very frequently mentioned in England is the *stone*, which is a legal weight there. The British Weights and Measures Act, 1878, defines the hundredweight as 8 stones, and somewhat similar weights with names meaning stone were in use in other European countries before they adopted the metric system. The name is simple and the magnitude apparently convenient, yet in this country we get along just as well without anything like it. A few 14-pound weights are still to be found with old weighing scales, or might perhaps be picked up in junk-shops, but they are called 14 pounds, not 1 stone; and new sets of weights used here don't include one of 14 pounds. In the same way our successors can look in the scrap heaps for our pound weights; we could get along as well with a unit of different magnitude from either the troy pound or the avoirdupois.

Another illustration is furnished by the *pole* (or perch, from the Latin *pertica*, meaning pole), a very old measure, most widely known and significantly named. As to the present use of this unit there is information in the report of the sixth annual meeting of the Ohio Society of Surveyors and Civil Engineers, held in January, 1885. It appeared (p. 120) that of the surveyors present there were five who made it their practice in surveying farm lands to express measures by this unit, six by the foot and eighteen by the chain. There is, however, no extraordinary convenience in a length of 5½ yards or thereabouts; if the pole were twice as long, or half as long, it would be as convenient for our purposes, and it has in fact varied nearly to that extent at different times and places.†

* The feasibility of this is more directly shown by the fact that our kindred in Scotland have actually used a unit of very different magnitude; the Scotch gallon prior to the introduction of the imperial measure held 13.66 kilos of water, while the numerous English, Irish, imperial and American gallons have held only about 4 or 5 kilos.

† The Irish perch was seven yards, and the acre 160 square perches. In discussing *British and Metric Measures* before the Institution of Civil Engineers, London, Jan., 1885, Mr. Hamilton-Smythe stated that "In Ireland, land purchased for engineering works had to be computed in Irish land measures, the conversions into which were at least as troublesome as the conversion of hectares into statute acres. Sub-contracts for fencing, walling and even some other kinds of masonry, were in Ireland set in Irish lineal perches, and various local measures had to be used there for purchasing lime, road-metaling and some other engineering materials." (Van Nostrand's *Engineering Magazine*, Oct., 1885, p. 324.)

The Irish acre, being 7,840 square yards, is 62 per cent. more than our acre (4,840

We know that we can express distances perfectly well by a unit of considerably different magnitude, so completely has it disappeared from among us. Our five friends in Ohio may be assured that the loss of the pole by the substitution of a different unit in their work will not be felt as a deprivation after the change shall be fully accomplished.

I have spoken of some units which we dispense with, though they are used elsewhere. There are also units which we use that other people dispense with. One is the American board measure, a superficial foot 1 inch thick. In England they get along without it, using the cubic foot and other units. We could get along, too, without using the foot at all. Another unit used here in Boston is the cubic fathom for earthwork, which we absurdly miscall a "square." In other places, and to some extent here, it is found that a much smaller unit serves as well for reckoning earthwork.

Finally, another unit that has gone out of use is the *league*. Its name is one of the best known among our weights and measures. It is preserved in our literature, used in our legislation and included in most of our arithmetical tables, the book-makers probably being anxious to round out their tables. They very seldom state its value correctly, but that does little harm, so completely has it disappeared from use as a popular measure. It was a good length for an itinerary measure, as I know from having some experience with a similar measure, the *legua* still in popular use in Mexico; but we can get along perfectly well without it and with nothing near to the same length in place of it. Likewise we can get along just as well without our outlandish mile* by substituting another unit of considerably different size.

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square yards), and 34 per cent. less than the hektar (which is 11,960 square yards) The use of such a measure in the United Kingdom justifies the inference that in the United States a unit very different from our acre could just as well be used.

*As to length, the mile is not conspicuously worse, nor better, than any other itinerary measure; the trouble is that between it and others of our units there is discord. The mile anciently in popular use in England was about half as long again as our present mile; facts about it are imperfectly known, except the fact that there was great confusion. The "old London mile" was 5,000 feet; and in books 5,000 feet was called a "geometrical" mile, which being 303 poles and 2 palms was regarded as incongruous. A mile of 320 poles finally became established, and is called a "statute" mile, because it was incidentally fixed by a statute of Queen Elizabeth. Its awkward relation to our other units is sufficiently accounted for by its being a Roman unit, separated from the other Roman units with which it was most closely connected, and misgrafted upon the English measure. Mile is abbreviated from the Latin *mille passuum* (as kilo is abbreviated from kilogram); and among English-speaking people the length of the mile exhibits some approximation to that of the Roman unit so named; the statute mile, the Scotch mile, the nautical mile and the Irish mile being respectively about 9, 22, 25 and 39 per cent. longer than the Roman. On the continent of Europe the name was very freely used, and was thrust upon itinerary and geographical measures regardless of length; Denmark still retains its *mil* of 24,000 Rhineland feet, and Russia has in its grand-duchy of Finland a mile of 36,000 Swedish feet. (See Encyclopædia Britannica, 9th Edition, Vol. IX, p. 218). The other nations of Europe have now adopted the metric system, and in several widely separated places the kilometer has been temporarily named *mil*, *mijle* and *miglio*. If it was an advantage of the Roman mile and the geometrical to bear a simple relation to the artisan's units, the foot and inch; if an advantage of the statute mile, the Scotch and the Irish, to bear a simple relation to the land surveyor's units, his field chain and acre; if an advantage of the nautical mile to bear a simple relation to an arc of the earth's circumference; then it is the superior advantage of the kilometer to bear at the same time simple relations to the artisan's units, the meter and centimeter, to the land surveyor's units, the dekameter and ar, and to the earth's quadrant.

In general our prospect of getting rid of customary magnitudes of units may be judged by our retrospect of having got rid of customary magnitudes of units.

3. The third point upon which I wish to insist is connected with the fact already stated, that pretty much every magnitude has been heretofore made a unit of measure; the result is that if a decimal system is constructed upon any conceivable base, it would be strange if some of the decimal multiples or sub-multiples did not hit close to the magnitudes of old customary weights and measures. At any rate, *the decimal system founded on the meter*, which is what now concerns us, *has a great many of its units coinciding substantially with old units.* Passing by some such coincidences in the case of the less used sub-units, which, like the eagle and dime in our monetary system, are of very subordinate importance, I will take up the principal metric units one after another, and compare them with old units, interspersing a few comments bearing upon their practical convenience.

The units of capacity can be disposed of very briefly. The principal metric unit of capacity bears the name of *liter*, which is of the same origin as the lb. and £, used to designate the principal British units of weight and value. The *liter* has substantially the same size as the quart, being intermediate between the United States liquid quart by which milk is measured for every well-regulated family, and the United States dry quart, by which oats are measured for every well-regulated horse. The *hektoliter*, the larger unit of capacity, is of about the same size as the barrel, which is very widely used for dealing in cement, oil, liquors, fish, pork, flour and other products. The name, meaning 100 liters, is analogous to hektograph, meaning 100 copies. Whatever convenience in size is possessed by the quart and the barrel,* is possessed likewise by the liter and hektoliter.

Similarly, passing on to weight units, the metric ton is substantially the same as the old ton, being intermediate between the ton of 2,000 pounds and that of 2,240. The *gram* corresponds to the scruple, previously in use as a medicinal weight, with but little variation in magnitude throughout Europe and America. Its wide diffusion was due to its having come from the *scrupulum* of ancient Rome along with other weights of the same series. The Greek physicians used the name *gramma* instead of the Latin *scrupulum;* thence we have instead of the awkward word scruple our present word *gram*, which has been made very familiar by derivatives like program, telegram, monogram and diagram.

The *kilogram* is the principal commercial unit of weight introduced by the metric reform, and it corresponds approximately to what has been used for centuries in the East and in Mediterranean ports.†

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* The following is an extract from the Public Statutes of Massachusetts (chap. lx., sec. 20): "The legal and standard measure of a barrel of cranberries shall be one hundred quarts," etc.

† To go into particulars, various weights, a large number of which were between 800 and 1,300 grams, have been in use under the name of *rottolo* in some of the Italian cities Sicily, Malta, Algiers and Morocco; under the name of *oke* in Ragusa (now Austrian territory), Hungary, Roumania, Servia, Greece, Turkey, Crete, Cyprus, Syria, Egypt and Tripoli; under the name of *maund* in Arabia; under the name of *seer* in India; and under still different names in a few other oriental countries. The name of *seer* was

A kilo is about the weight that a man can easily manipulate with one hand; hence tools and other articles, like a hatchet, or a pistol, or a bottle of wine, or a volume of United States public documents, are apt to weigh about a kilo; and the Public Statutes of Massachusetts (chap. lx., sec. 3) provide that "a loaf of bread for sale shall be two pounds in weight," which is nearly one kilo.

It remains to discuss linear units. The principal one has the name of *meter*, an old English word sufficiently intelligible to people who define real estate by "metes and bounds." A measuring rod was designated in the Bible and in Shakespeare by the word *meteyard*, now obsolete, in which the syllable yard meant rod. The name *meter* is now given to a length substantially the same that has from time immemorial been the English standard and has been called a yard or ell. The two names were formerly used indiscriminately. The ancient statute of England, entitled "*Compositio ulnarum et perticarum*," declared that three feet made an ell (*ulna*), and 5½ ells a perch. Latterly the names ell and yard have been applied to separate measures in the ratio of 5 and 4. The exchequer standard of length constructed in Queen Elizabeth's reign shows both measures upon the same bronze bar by beds or sockets into which the standard yard and the standard ell fit; and the colonial legislation of Massachusetts, Maryland, Virginia and North Carolina (and probably of other colonies) provided for standards of both the ell and the yard. The Scotch ell was a different measure, which Professor Rankine, in his *Civil Engineering*, says is sometimes found upon old plans. It was 94+ centimeters, or 37 Scotch inches, perhaps arising from throwing in one inch with every three feet. The English ell of 114+ centimeters is regarded especially as a cloth measure. It continued to be included in our school arithmetics down to about the time when the meter was introduced into them. In Heyl's United States Duties on Imports, 1883, a work officially recognized by the Treasury Department, are tables giving superficial measure, weight and price per lineal yard and meter and also per *aune*, which our dictionaries spell also *auln*, and derive from the Latin *ulna* (el-bow). Silks from Lyons are still

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given to the kilo by the Act of 1871 providing for its introduction into British India. The name of *oke* was given to the kilo by a decree of the Sultan establishing it in Turkey from March 1, 1882. The name of *mina* was given to the kilo when it was introduced into Greece. Among the earliest of known weights is the Assyrian *mina*, of about 1,010 grams, now in the British Museum, as stated in the ninth edition of the Encyclopædia Britannica, Vol. XVII., p. 631, under title *Numismatics*. The late H. W. Chisholm, who was Warden of the Standards, gave it as 993.4 grams on p. 41 of his *Weighing and Measuring*, published by McMillan & Co., London, 1877, and he referred to Layard's *Nineveh and Babylon* for further information. *Mina* is akin (and so probably is *maund*) to the Hebrew word *maneh*, which is translated "pound" in the English Bible, I. Kings x. 17, but meant two or three times as much as a pound. The revised version of the Old Testament, published last year, would have been more accurate if it had translated it "kilo." This everybody may verify by comparing II. Chronicles, ix. 16, and the dictionary definitions of *mina*, *maneh* and *shekel*. English dictionaries also contain *oke*, to which Webster assigns the same origin as to "ounce," and *seer* is in Worcester. *Rottolo* appears to come from the Arabic for pound.

In the ancient series of Scotch weights the *trone pound* (which is imperfectly described both by Webster and Worcester) had somewhat varying values, the largest being nearly 800 grams. After it was forbidden by law, trone weight continued to be used for butter, cheese, meat, etc.

imported into the United States in these aunes. This aune is five quarters of a yard or 114+ centimeters; that is, it is really the English ell. Though it is given by Heyl as a measure of Lyons and Switzerland, it is probably used there only for goods that are to be exported. The old French aune was different; Talleyrand is cited to the effect that in France a hundred years ago there were "18 different legal yards (aunes) measuring $299\frac{80}{100}$ to $597\frac{20}{100}$ lignes."* That is from 67 to 135 centimeters; half way between these two extremes would be 101 centimeters. Various measures approximating to the length of the meter, named *aune*, *stab* (in English, staff), or *elle*, were formerly used in Switzerland, Germany and Austria. The name of *el* was given to the meter in Holland, and used for fifty years (1821–1870) before the metric names were introduced there. The name of *aune* was similarly given to the meter in Belgium from 1821 to 1836. The name of *stab* was permitted to be given to the meter in Germany from 1868 to 1884, but the permission was not availed of.†

The English yard, equal to 91+ centimeters, is used for general purposes, and among others for distances on land and water, race-courses, range of projectiles, and measurement of paving, plastering, painting, masonry, and earthwork. Engineers also buy their drawing paper by the yard. A recent illustration of its use in the United States is the notice from the Coast Survey Office, published in the newspapers last fall, describing in yards the position of some dangerous shoals in East River, New York. In Great Britain and her colonies the yard is still more freely used than in the United States.

The length unit of Spain and all Spanish America corresponded to our yard, and had in different places slightly different values, generally from 83 to 87 centimeters. It was called the "*vara*," which means "rod," and is the same as the disused English word vare, according to our dictionaries. In Texas, where it continues in general use by land surveyors to-day, as is required by the laws of the State, it is nearly 85 centimeters. The *varas* of Brazil and Portugal were about 109 or 110 centimeters. In India, various measures have been used under the name of *guz* or *gujah*, many of which approximated to the meter. The government of Mysore, a native State of Southern India, established for the measurement of land a *guz* equal to about 97 centimeters. Measures of about a meter's length have also been used in some of the minor oriental countries.‡ There is preserved in the British Museum

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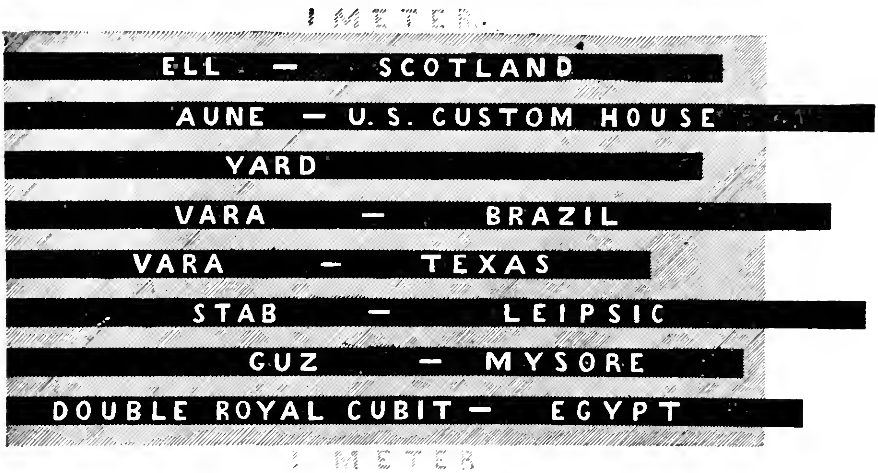
* Majority report by Messrs. Coleman Sellers and W. P. Tatham to the Franklin Institute, a copy of which was officially transmitted to the Boston Society of Civil Engineers, Nov. 20, 1876.

† The meter was then thoroughly established in the countries neighboring to Germany, while her own people were remarkably well educated and in possession of great facilities for the dissemination of knowledge; hence it was easy to call the meter by its proper name. In 1821, on the contrary, when the Low Countries adhered to old names, they had some reason; the metric reform then appeared to be an experiment at the best, and in some places a failure: passenger railroads, ocean steamship lines and the electric telegraph did not exist; and international commerce, the publication of newspapers and popular education were comparatively insignificant.

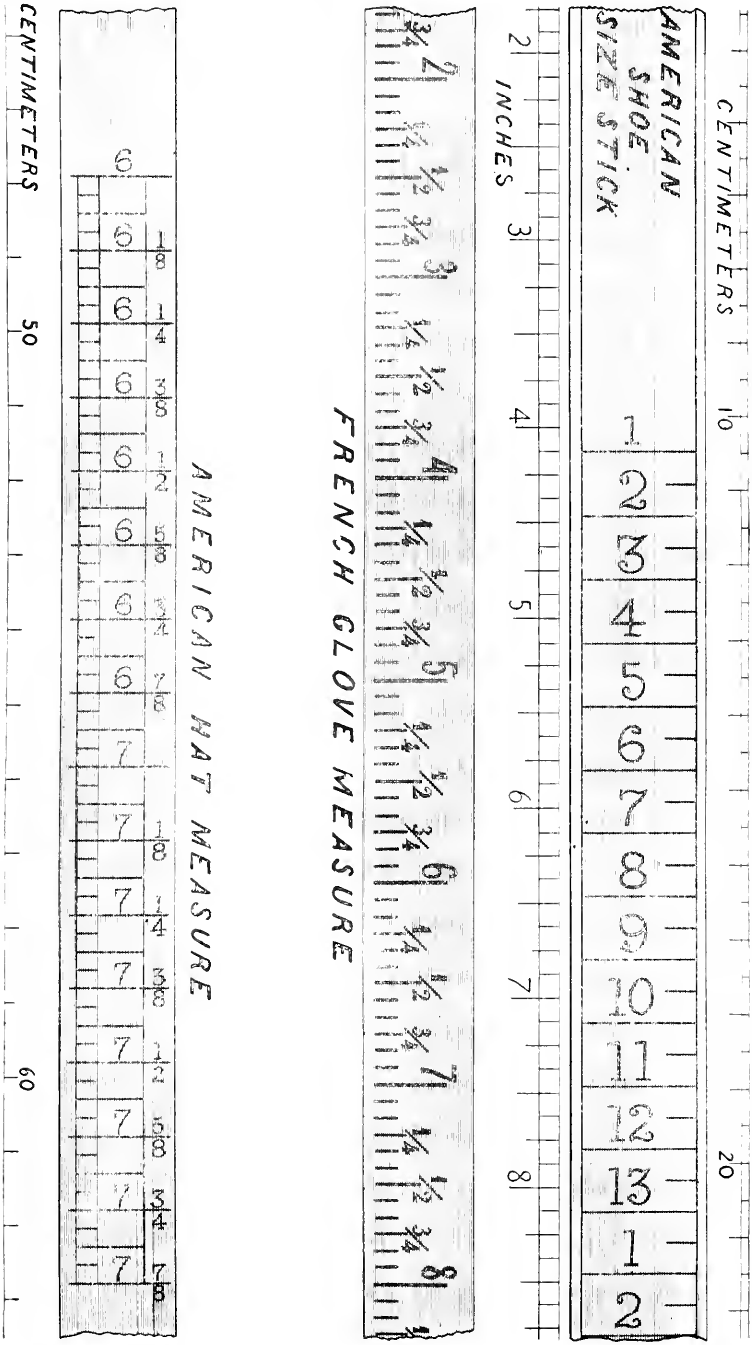
‡ Authentic information about Indian weights and measures from 150 different trading places was procured by the East India Company about sixty years ago, and committed to Dr. Patrick Kelly, who published it in his *Universal Cambist.*

an original ancient Egyptian rule, which was found inclosed in the masonry of a building at Karnac, where it must have been left during construction thousands of years ago. This rule is 105 centimeters long, being double the royal cubit, which was used for architectural and engineering work in ancient Egypt, as the dimensions of remaining structures attest. The accompanying diagram shows the relative size of some of the principal units of length above mentioned. So a measure of about the length of the meter has been used in the most widely separated times and places, and especially in most of the countries and islands washed by the Atlantic Ocean immediately before the introduction of the metric system: from which at least the negative conclusion may fairly be drawn that there is no marked inconvenience in size about the meter. Whatever convenience in size there is about the yard and these other



old measures, there is about the meter. From my observation of the use of such measures for dry goods and from my own use of the meter for some years in railroad surveying, I draw the positive conclusion that the meter is of convenient length.

The *centimeter*, bearing the same relation to the meter that the cent bears to the dollar, is of about the same magnitude as the barleycorn, which appeared in the statute *Compositio ulnarum et perticarum*, already cited, as if it were the basis of English measures, and which has come down to the present day in our arithmetical tables. Such a length has actually been introduced as a measure in the United States for several special purposes. The shoe-stick or measure for the sizes of shoes is marked as shown on the diagram (next page), where centimeters and inches are drawn adjacent for comparison. The difference between one size and the next, or the unit of size-numbering, is but little less than a centimeter, and the difference between a child's size and the adult's size of the same number is a little more than a decimeter, as is also the distance from the end of the measure to the first mark. None of the sizes

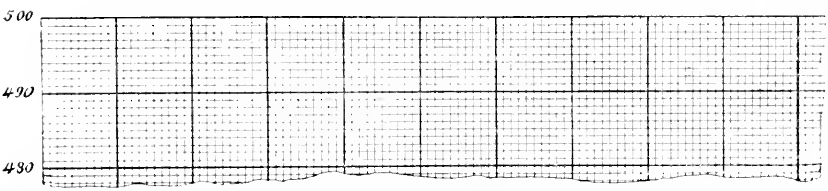

CENTIMETERS
AMERICAN SHOE SIZE STICK
INCHES
FRENCH GLOVE MEASURE
AMERICAN HAT MEASURE
CENTIMETERS

has an integral number of inches length; and it does not appear why this odd unit of 0.8467 cm., or 0.3333 inch, is established, when the inch is used for the other shoemaker's measurements around the foot, unless it is because especial convenience is found in it. The diagram also shows the graduation of the hat measure, which is applied around the interior circumference of the hat, and determines the number 7, 7⅛, 7¼, etc., which designate the sizes of hats. The intervals between these successive numbers on the measure are almost exact centimeters, as is seen by comparing the scale drawn adjacent; and the distance apart of the units 6 and 7, for instance, or from 6⅝ to 7⅝, approaches a decimeter.

It appears as though there would be in the case of gloves, as well as in that of shoes and hats, an advantage in a unit of the size of a centimeter over a unit so large as an inch, but gloves are in fact sold by numbers which correspond to the measurement around the hand in old French *pouces*, or inches, in countries where the metric system is in general use as well as where it is not.

Sheets ruled in centimeters and millimeters have been used for plotting diagrams in the Locks and Canals Office at Lowell for about thirty years, and in the Essex Co.'s office at Lawrence about fifteen years. As the measurements and work of these companies are in feet and other old units, it would appear that the selection of metric units for their diagrams is because they happen to be convenient in size. A copy of the corner of a sheet is appended, showing the style of ruling.

Proprietors of the Locks and Canals on Merrimack River, Lowell, Massachusetts



The metric system of measurement was adopted about sixteen years ago by the American Watch Company at Waltham, Mass., because of its convenience, in spite of their being in the midst of a community that did not use it. The centimeter is their unit. This might serve as a useful hint to people who say, in an unthinking way, apparently, that the meter is too large a unit and the millimeter too small a one for mechanical purposes. In Germany, the millimeter has been chosen as the unit for mechanical purposes, presumably because the Germans are better suited by the smaller unit. In the shops of William Sellers & Co., of Philadelphia, the metric system has been used some twenty-five years for building injectors. Mr. Coleman Sellers said in regard to this in 1876 (Transactions Am. Soc. C. E., Vol. V., p. 366): "So we adopted the meter as the unit of measure in this case, and have seen no reason to regret having done so. But its continued use during many years has only confirmed us in the advantage of the inch, a unit which can be divided into any convenient subdivision at the option of the user. The Waltham Watch Factory, or any other manufactory using only short

measurements, will find the metric system as convenient as we have found it in its use in building injectors, but for those shops that deal in larger sizes of parts, the inch is very much more convenient." Nov. 4, 1880, he said at the meeting of the American Society of Mechanical Engineers, in his paper referring to the same subject: "Once having perfected an organization in this department we became fixed in its continuance. Precisely the same reasons why we cannot change our general system into the metric hold against our giving up the metric system in the departments where it is in use." It is plain, therefore, that any inconvenience Mr. Sellers may find in the size of the metric units is a very subordinate consideration in his mind, so far as making injectors is concerned. The ground of his stubborn opposition to the metric system is the difficulty of making a change. Wm. Sellers & Co. have not introduced metric screw-threads even into their injector department. The machine shop of the American Watch Company uses a series of metric screws of 45 sizes, ranging from .05 of a centimeter in diameter, with 100 threads per centimeter, up to 3 centimeters in diameter with 3 threads per centimeter, which latter, by the way, is not a very small size, being nearly equivalent to 1¼ inches in diameter, with 7 threads per inch. Metric threads have been used in France, differing from one another, and from the American Watch Company's series. In Germany, the sizes of screws that were previously in use have not yet been abandoned, although the old units for other mechanical measurements generally have been abandoned; somewhat as in France the old numbering of gloves has not been superseded by the metric system, although most articles of clothing are measured in centimeters. As no uniform metric screw-thread system for ordinary bolts and nuts* has yet been generally adopted even in countries that have adopted the metric weights and measures for other purposes, the desirability of international uniformity, which is a subsidiary reason why we should adopt the metric system for other purposes, is a reason why we should hesitate to adopt it for screw-threads at present. The rivalry of the Whitworth screw-threads generally used in Great Britain, and the U. S. standard generally used in this country, is liable to result sooner or later in drawing attention to the metric threads. The greater delay in introducing metric dimensions in screw-threads than in other things may be attributed to the uncommon difficulty of making any change whatever in them. That it is not due to any want of adaptation of the metric system to screw-threads is seen by comparing tables of metric and old screws. Though as a practical matter it seems a little premature, the comparison may prove an instructive study. As an illustration of the simplicity of the metric system and of its convenience in manufacturing, it will do as well as something more immediately coming into use. The metric series presented in this comparison is substantially that of Delisle, master machinist at Carlsruhe; but it embodies the slight modification made by Professor Reuleaux, of Berlin, who publishes it as useful for technical instruction, though not immediately available for constructive work, in

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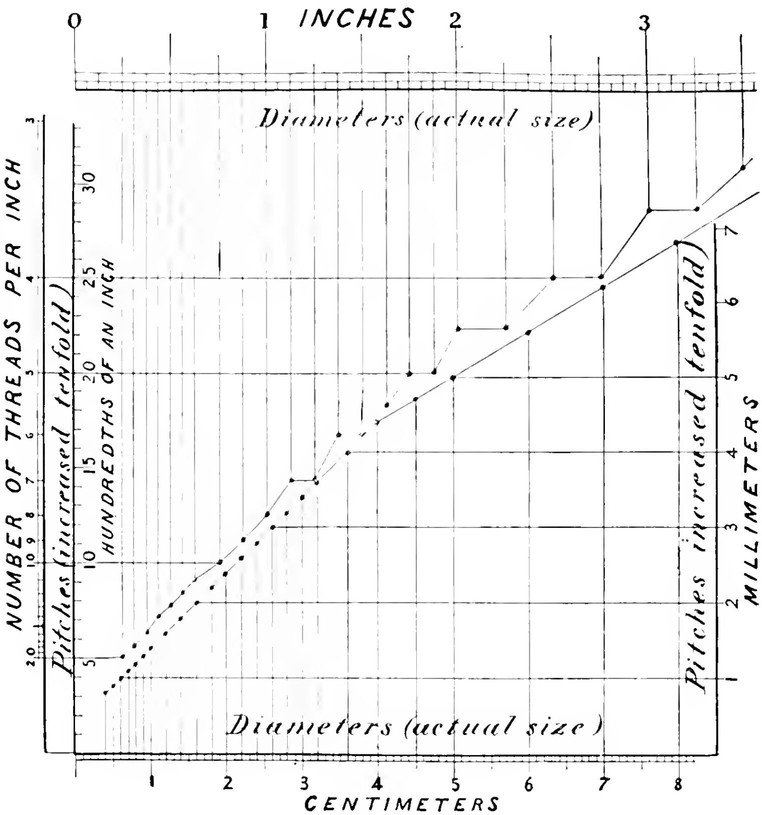
* An account of the Swiss system of small screws, such as are used in watch manufacture, was given in the report of our Metric Committee, presented March 19, 1884. *See* JOURNAL OF THE ASSOCIATION, Vol. III., p. 130.

his *Constructor* (See 4th German Edition, Brunswick, 1882, or 2d French Edition, Paris, 1881.)

Let us first consider the selection of diameters of bolts to constitute the standard sizes. This is exhibited at the top and bottom lines of the diagram below, where against the ordinary scales of length the diameters of the metric and United States series are marked by vertical lines. There is a similar correspondence of diameters to length units in the metric series, in the United States standard series and in the Whitworth



series. In all of these the largest diameters correspond to consecutive subdivisions of the unit of length, and the smallest diameters to consecutive smaller subdivisions, while among the intermediate diameters there is less regularity in the spacing, because the intervals want to change without changing abruptly. Both inch and meter measures permit a good series to be made.

Let us next consider the relation of pitch to diameter. The comparison is easily made by looking at the dots on the accompanying diagram, which are plotted by making the diameters abscissas and the pitches ordinates.

It is seen at a glance that the relation of pitch to diameter is regular in the metric scheme and irregular in the United States standard practice. It can be expressed in the metric scheme by simple formulas—

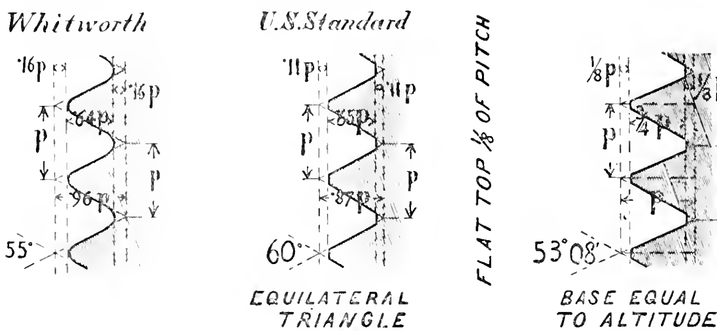
$$\text{Pitch} = 0.4 \text{ mm.} + \tfrac{1}{10} \text{ diameter},$$

and

$$\text{Pitch} = 2 \text{ mm.} + \tfrac{6}{100} \text{ diameter},$$

according as the diameter is less or more than 40 mm. If intermediate diameter sizes should be required (which is unlikely) they could conveniently have intermediate pitches to correspond according to the same formulas, and not break the regularity of the relation. On the contrary the United States series admits of no such formula,* and the Whitworth system, though not precisely the same, is in this respect very similar to the United States standard.

The most marked difference between the Whitworth system and the United States standard is in the profile of the thread, as exhibited below.



The Whitworth thread has an angle of 55 degrees, corresponding to a triangle whose altitude is 0.96 times its base; and as one-sixth of this perpendicular distance is rounded off at the root of the thread and one-sixth at the top, the depth of the Whitworth thread is 0.64 times the pitch. The United States standard thread has an angle of 60 degrees, corresponding to a triangle whose altitude is 0.87 times its base, and as one-eighth of this perpendicular distance is cut off at the root of the thread and one-eighth at the top, the depth of the thread is 0.65 times the pitch. The 60 degree angle, being the angle of an equilateral triangle, is more easily established, verified and adhered to than the 55 degree; and the flat top and bottom are simpler to make than the rounded form. This difference of angle is independent of the unit of length. The United States standard form of thread is just as well adapted to the meter as to the inch; but if it should be adopted for metric screws, Professor Reuleaux would recommend a little greater pitch in proportion to diam-

* The formula, $p = 0.24 \sqrt{D + 0.625} - 0.175$, sometimes given, is comparatively involved, and it does not perfectly express the relation of pitch to diameter; for instance, a ¾-inch bolt has really 10 threads per inch, but this formula would give 9.4.

eter than is shown on the foregoing diagram, so that the formulas would be, if p denotes pitch and d diameter—

$$p = 2\,d \text{ from } d = 4 \text{ to } d = 8 \text{ mm.}$$
$$p = 0.8 + 0.1\,d \text{ from } d = 8 \text{ to } d = 40 \text{ mm.}$$
$$p = 1.6 + 0.08\,d \text{ from } d = 40 \text{ to } d = 80 \text{ mm., or more.}$$

The metric scheme on the previous diagram showed everywhere a pitch less in proportion to diameter than the United States standard, because it is intended for a different form of thread. Most other screw systems have a smaller angle than 60 degrees, and Professor Reuleaux prefers the angle (53 degrees 8 minutes) belonging to a triangle whose

U. S. Standard Bolts.			Metric Bolts and Nuts.									
							Short diameter of hexagonal nut.		Washer.		
Outside diameter.	Effective diameter.	No. of threads per inch.	Outside diameter of bolt.	Pitch.	Depth of thread.	Effective diameter of bolt.	Finished.	Rough.	Diameter.	Thickness.	Thickness of bolt-head.
In.	Inch.		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
....	......	....	4	0·8	0.60	2.80	9	Seldom left rough below 10 mm. diameter.	12	1	3
....	......	....	5	0.9	0.68	3.65	10.5±		14	1	3.5
¼	.185	20	6	1.0	0.75	4.50	12		16	1	4
....	......	....	7	1.1	0.85	5.35	13.5±		18	1.5	5
5/16	.240	18	8	1.2	0.90	6.20	15		20	1.5	6
⅜	.294	16	9	1.3	0.98	7.05	16.5±		22	1.5	6
7/16	.345	14	10	1.4	1.05	7.90	18	21	24	1.5	7
½	.400	13	12	1.6	1.20	9.60	21	24	28	2	8
9/16	.454	12	14	1.8	1.35	11.30	24	27	32	2	10
⅝	.507	11	16	2.0	1.50	13.00	27	30	36	2	11
¾	.620	10	18	2.2	1.65	14.70	30	33	40	3	13
....	......	....	20	2.4	1.80	16.40	33	36	44	3	14
⅞	.731	9	22	2.6	1.95	18.10	36	39	48	3	15
....	......	....	24	2 8	2.10	19 80	39	42	52	3	17
1	.837	8	26	3.0	2.25	20.50	42	45	56	4	18
1⅛	.940	7	28	3.2	2.40	23.20	45	48	60	4	20
1¼	1.065	7	30	3.4	2.55	24.90	48	51	64	4	21
1⅜	1.160	6	32	3.6	2.70	26.60	51	54	68	4	22
1½	1.284	6	36	4.0	3.00	30.00	57	60	76	5	25
1⅝	1.389	5½	40	4.4	3.30	33.40	63	66	84	5	28
1¾	1.491	5	45	4.7	3.55	37.95	70	73	92	6	32
1⅞	1.616	5	......	......	......	......	......	......	......	......	......
2	1.712	4½	50	5.0	3.75	42.50	76	79	100	6	35
2¼	1.962	4½	60	5.6	4.20	51.60	89	92	116	7	42
2½	2.176	4	......	......	......	......	......	......	......	......	......
2¾	2.426	4	70	6.2	4.65	60.70	102	105	132	7	49
3	2.629	3½	......	......	......	......	......	......	......	......	......
3¼	2.879	3½	80	6.8	5.10	69.80	115	118	148	8	56
3½	3.100	3¼	......	......	......	......	......	......	......	......	......
3¾	3.317	3	......	......	......	......	......	......	......	......	......

altitude is equal to its base. This has the advantage of ready verification, like the United States standard angle. Taking off one-eighth at the top

and one-eighth at the bottom of the thread, he has the depth of the thread exactly three-fourths of the pitch. Hence, if the pitch were the same with this thread as with the United States standard thread, the depth would be a little greater and the strength of the bolt reduced. In order to keep up the effective diameter when the depth of the thread is 0.75 of the pitch, a smaller pitch is required than when 0.65.

The metric screw-threads are given in tabular form on preceding page, and with them are put three columns from the table of U. S. standard threads which enables comparisons to be made in a little different way from before. It takes more figures to express the nominal diameters and threads per inch in the U. S. series than the diameters and pitches for the same number of screws in the metric series. The effective diameters in the metric series are mostly exact tenths of a millimeter, and are always expressed accurately and in the same form as the other dimensions. In the U. S. series, on the contrary, they are irregular quantities; they are expressed decimally, while the other dimensions are binary fractions; and they are not exact unless the decimals are carried out to an indefinite number of places. In respect to the other dimensions of the head and nut, there is no important difference between the systems, and those of the U. S. standard series are not copied in the table. They are easily accessible. Being written in 16ths and 32ds of an inch, they require more figures than the metric dimensions. The formulas are here given. The depth of the nut equals the outside diameter of the bolt in both series.

	Metric.	U. S. Standard.
Depth of head = ...	$\frac{7}{10}\,d$	$\frac{3}{4}\,d + \frac{1}{16}''$
Short diameter of finished square or hexagonal nut or head = ...	1 mm. $+ d + 5\,p$	$1\frac{1}{2}\,d + \frac{1}{8}''$

In February, 1884, in a lecture before the Franklin Institute on *Standards of Length and their Subdivision*, Mr. Geo. M. Bond explained the exquisite accuracy with which the Pratt & Whitney Company have been making gauges for manufacturing U. S. standard screw-threads so that bolts and nuts should be interchangeable. He exhibited the standard line-measure bar upon which are ruled the bottom diameters of the U. S. standard series of threads, and stated that the screw by means of which Prof. W. A. Rogers transferred the graduated lines to this bar was a metric screw. When the railroad companies and bolt manufacturers, in their efforts to get accurate inch standards, resort to a metric screw for the purpose, it would seem to be time for us to learn a little about metric screw-threads.

Metric screw-threads could be cut on lathes with inch-divided leading-screws, if that were desired, by the use of a change wheel with 127 teeth ; for 127 millimeters equal five inches. In comparisons made with the utmost refinements known to science there is so slight a variation from that value that it would be imperceptible in the measurements of the machine shop. Professor Rogers found (see Proceedings American Academy of Arts and Sciences, 1882–3) the length of the meter in inches to be 39.37027, according to which 0.127m. is 5.000024 inches, a variation from 5 inches of less than one part in 200,000.

To sum up, what has been done is to exhibit the magnitudes of many of the principal metric units by comparison with the old units which they are supplanting, and to exhibit some of the evidence which shows the metric units to be of sizes convenient for practical work.

THE THEORY OF THE AMMONIA REFRIGERATOR.

BY PROF. C. M. WOODWARD, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read February 3, 1886.]

The special characteristic of ammonia which gives it value as a refrigerating agent is that it becomes (or remains) a liquid under a high pressure at the ordinary temperature, and under ordinary atmospheric pressure at a low temperature. It boils at $-40°$ F. in the atmosphere, and at $+98°$ when under a pressure of thirteen atmospheres. Nevertheless, though boiling at a low temperature, it cannot boil without a continuous supply of heat; in other words, ammonia has no more tendency to boil of itself than has water in the tea-kettle. When poured into or along a warm vessel, the heat in the vessel suffices to boil the liquid for a time; but when a certain point of low temperature and reacting pressure is reached, no more boiling will take place till more heat is supplied to the liquid through the walls of the vessel.

If now liquid ammonia is allowed to boil in a coil of iron pipe, absorbing heat from the substances enveloping the coil, while the ammonia gas flows away to a pump by which it is forced, under a very high pressure, into a second coil enveloped in moderately cool substances, it is evident that the heat absorbed during the process of evaporation in the first coil will be given up again as the gas liquefies in the second coil. The liquid ammonia being now returned to its first condition, may go the round again With a suitable supply of ammonia and a pump in continuous operation, it is easily seen that heat may be continuously withdrawn from one set of substances and given up to another.

The process is so closely analogous to that of heating by steam, as to justify a brief comparison of the two. $\left\{\begin{matrix}\text{Water}\\ \text{Liquid ammonia}\end{matrix}\right\}$ boiling at a $\left\{\begin{matrix}\text{high}\\ \text{low}\end{matrix}\right\}$ temperature, absorbs a vast amount of heat from the $\left\{\begin{matrix}\text{fiery furnace}\\ \text{chill tank or chamber}\end{matrix}\right\}$; then flowing in a state of gas under $\left\{\begin{matrix}\text{high}\\ \text{low}\end{matrix}\right\}$ pressure with a large amount of *latent* heat involved in its energy, it gives it all up again as it liquefies $\left\{\begin{matrix}\text{without}\\ \text{with}\end{matrix}\right\}$ the use of a condensing pump. The methods of finding the amount of heat transposed in either case are quite the same. From experimental data we find how much heat one pound of the liquid absorbs as it evaporates, under the given conditions; next we find by proper measurements how much liquid, *i. e.*, how many pounds, are evaporated per hour.

Let us first solve the ammonia problem in a gener form.

Let p_1 and T_1 denote the pressure and absolute temperature of the liquid before it enters the "chill" coil, the pressure being in atmospheres and the temperature in degrees Fahrenheit. Let p_2, T_2 be the pressure and temperature of the boiling liquid in the coils, and v_2 the volume of one pound of the gas under the conditions p_2, T_2. It is assumed that the condition p_2, T_2 is maintained by the pump, liquid always being in the coil pipe, so that the gas is in a *saturated* condition. If H denotes the vaporizing heat (the amount of heat absorbed during evaporation, and

without change in temperature) per pound of the liquid, we have from the formulæ of thermodynamics:

$$H = \frac{2116}{772} v_2 \ T_2 \frac{d\,p_2}{d\,T_2} \qquad (1)$$

The means at my command for computing the volume v_2 are chiefly theoretical. From the composition of ammonia gas, by familiar methods, I readily find the general value of $\frac{v\,p}{T}$ to be 0.0423, the gas being superheated. Hence $v = \frac{T}{p} 0.0423$. At the point of saturation v is doubtless less than the value given by this formula.*

However, it is not important to know the exact value of v at the point of saturation, inasmuch as the gas generally becomes superheated to a greater or less degree before it leaves the chill coil, and the heat absorbed during this superheating *exceeds* the amount needed to equally raise the temperature of a perfect gas by just the amount required to make my formulæ good. As the volume is very closely given by the formula $v = \frac{T}{p}$ 0.0423, except in the immediate vicinity of the point of saturation, no sensible error is introduced by substituting it in the value of H, which thus becomes:

$$H = \frac{2116}{772} 0.0423 \frac{T_2{}^2}{p_2} \left(\frac{d\,p}{d\,T}\right)_2 = 0.116 \frac{T_2{}^2}{p_2} \left(\frac{d\,p}{d\,T}\right)_2 \qquad (2)$$

Before entering the pump, upon leaving the cooling pipes, the gas is always superheated. The heat absorbed in addition to the vaporizing heat is given by the equation:

$$h = (T_3 - T_2)\,k,$$

in which T_3 is the temperature of the superheated gas, and k its specific heat (or the heat required to raise its temperature one degree, the pressure remaining unchanged.)

The amount of *useful cooling* done per pound of liquid ammonia may now be given. From the sum of H and h must be subtracted the heat supplied by the liquid ammonia which enters the cooling pipes at T_1, and is cooled down to T_2. If K is the specific heat of the liquid, this amounts to $(T_1 - T_2)\,K$.

Hence the cooling effect of the passage of one pound of ammonia is

$$C = 0.116 \frac{T_2{}^2}{p_2} \frac{d\,p_2}{d\,T_2} + (T_3 - T_2)\,k - (T_1 - T_2)\,K. \qquad (3)$$

Our next step is to find the amount of ammonia which passes through the coils per unit of time, which, for convenience, I shall take as one hour. There are several methods of measurement possible:

1. By a gas meter in the return pipe supplying the pump.
2. By a liquid meter in the pipe leading to the feed valve.
3. By indicator cards upon the pump.
4. By measuring the pump itself and determining the volume pumped per revolution.

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* As is the case with steam. The volume of steam at the point of saturation at 212° is about 3 per cent. less than its behavior while superheated would lead us to suppose. Carbonic acid departs very much from the volume of a perfect gas when near the point of saturation.

The great uncertainties in regard to clearance, valve and port spaces, and temperature in the pumps, render the third and fourth methods less trustworthy than either the first or second. The *first* method, by gas meter, appears to offer the greatest accuracy. The temperature T_3 of the gas should be taken as it enters the meter. The pressure is, of course, p_2. If V is the recorded volume, in cubic feet, passing the meter per hour, its weight will be:

$$W = \frac{V}{v_2} = \frac{V p_2}{T_3 \; 0.0423}, \tag{4}$$

and $W\,C$ is the cooling effect of the apparatus per hour.

Inasmuch as the quantities $(T_3 - T_2)\,k$ and $(T_1 - T_2)\,K$ are both small compared with H, it may be sufficiently exact to assume that their difference is zero. In that case C, as given by equation (3) becomes:

$$C_1 = 0.116 \, \frac{T_2^2}{p_2} \, \frac{d\,p_2}{d\,T_2}, \tag{5}$$

and the total cooling effect per hour is:

$$W\,C_1 = \frac{0.116}{0.0423} \cdot \frac{V\,T_2^2}{T_3} \left(\frac{d\,p}{d\,T}\right)_2. \tag{6}$$

The quantities V, T_2, T_3 and p_2 are to be directly observed by means of the meter, thermometers and a pressure gauge. I assume that they are constant for the hour. It will be borne in mind that $T° = t°$ Fahrenheit $+ 459°$.

k is 0.51: and K may be taken as 0.75. T_2 and $\left(\frac{d\,p}{d\,T}\right)_2$ are to be taken from the diagram on the next page,* in which is drawn to scale a curve showing the relation of pressure and temperature of saturated ammonia gas as determined by Faraday.

In a practical example investigated by me in 1883, I found W by measuring the pump, and arrived at the result that 87 pounds of ammonia passed through the apparatus in one hour.

$$T_1 = 459 + 98 = 557°.$$
$$T_3 = 459 + 30 = 489°.$$
$$p_2 = \tfrac{3}{2}.$$

From the curve I found that

$$T_2 = 459 - 23 = 436.$$
$$\left(\frac{d\,p}{d\,T}\right)_2 = 0.035.$$

Substituting these values in equation (3), I get $C = 514.5 + 27 - 90.7 = 451$.

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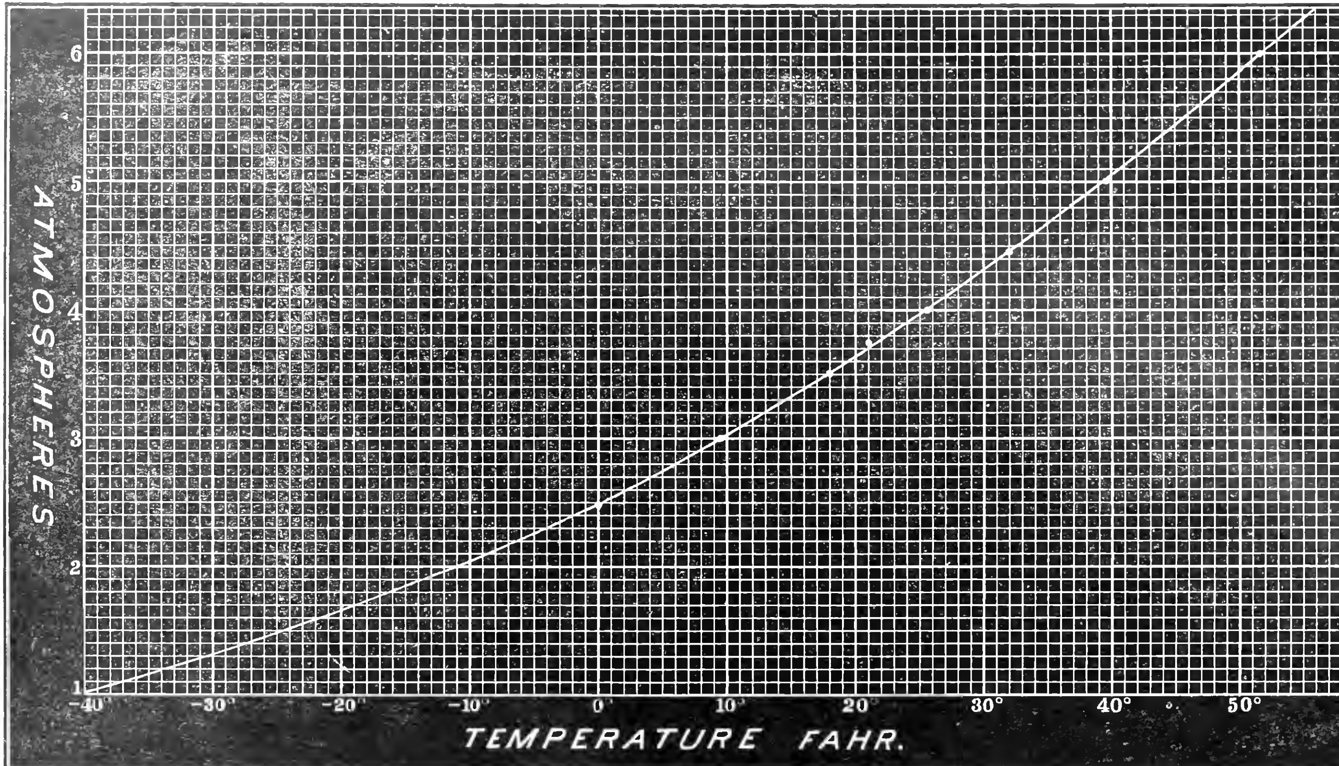
* The equation of the curve shown in the diagram has been approximately obtained by a former student of mine, Mr. J. H. Kinealey, dynamic engineer. It takes the following form:

$$a\,t = \left(p + b\right)^n$$

t being the absolute temperature, p the pressure in atmospheres, a, b, n constants, as follows:

$$\text{Log. } a = \bar{3}.4120408.$$
$$\text{Log. } n = \bar{1}.1606501.$$
$$b = 0.726.$$

The equation may be taken as accurate between 1 and 6 atmospheres. The general value of $\frac{d\,p}{d\,T} = \frac{a}{n}\,(p + b)^{1-n}$.



SATURATED AMMONIA GAS

Hence, $W\,C = 87 \times 451 = 39{,}237$ heat units per hour. This is equal to the heat absorbed by the *melting* of 276 pounds of ice at 32°, or $3\frac{1}{4}$ *tons of ice in twenty-four hours.*

Had p_2 been 2, instead of $\frac{3}{2}$, while V and T_3 remained the same, equation (4) shows W would have been 116 instead of 87 : T_2 would have been $459 - 11 = 448$, and $\left(\frac{d\,p}{d\,T}\right)_2$ would equal 0.0421.

These values in equation (3) give $C = 494.7 + 21 - 81 = 435$; so that $W\,C = 116 \times 435 = 50{,}460$ heat units per hour—a great increase over the former amount.

Similarly, had $p_3 = \frac{5}{2}$, T_2 would have been 459.5 (practically 0° Fahrenheit), and $\left(\frac{d\,p}{d\,T}\right)_2$ 0.0486.

Whence, from equation (4) $W = 145$, and from equation (3) $C = 476 + 15 - 74 = 417$, and $W\,C = 145 \times 417 = 60{,}465$ heat units per hour.

The important effect of increasing the pressure p_2 is thus evident, though it should not be overlooked that the temperature of the refrigerating pipes rises as p_2 rises.

As before remarked, the heat absorbed in the "chill" coils is to be given up later by the condensing gas in the "condenser" coils. But not that heat alone. The work of the engine driving the pump takes the form of heat imparted to the gas, and this, as well as the other, is to be given up in the condenser.

If the gas is pumped from a pressure p_2 to the pressure P_1, the immediate effect is to greatly increase the temperature from T_3 to T_4, which is given by the equation :

$$T_4 = T_3 \left(\frac{p_1}{p_2}\right)^{\frac{41}{141}} = T_3 \left(\frac{p_1}{p_2}\right)^{0.291} \qquad (7)$$

The work (in heat units) done by the engine in compression is, per pound of gas,

$$(T_4 - T_3)\,0.391 = T_3 \left(\left(\frac{p_1}{p_2}\right)^{0.291} - 1 \right) 0.391 \qquad (8)$$

Which, when multiplied by W and added to $W\,C$, gives the total amount of heat which is to be withdrawn from the compressed gas per hour in order to allow it to condense to a liquid at the initial temperature and pressure T_1, p_1.

This amount is :

$$S = W \left[C + T_3 \left(\left(\frac{p_1}{p_2}\right)^{0.291} - 1 \right) 0.391 \right] \qquad (9)$$

If this heat is carried off by running water, which, when flowing away has a *mean* temperature $D°$ *higher* than it had on entering the condenser, the amount of water needed per hour to supply the condenser (including the water jacket of the pump) is :

$$\frac{S}{D°} = \text{hourly water supply.} \qquad (10)$$

To illustrate the use of the formulæ, let $T_3 = 489$; $p_1 = 13$; $p_2 = 2$; then $T_4 = 459 + 384 = 843$, by equation (7). From equation (9) obtain

$S = 116\,(435 + 138.4) = 66{,}514$; and if $D^\circ = 50^\circ$, the hourly water supply $= 66.514 \div 50 = 1{,}330$ pounds.

[*Note.*—I have made no allowance for heat radiated nor for that absorbed by supply and return pipes from undesirable sources. Such allowances must be made separately for each plant.]

PILE DRIVING.

By E. H. Beckler, Member of the Western Society of Engineers.
[Read March 2, 1886.]

The notes for this paper have been gathered from the construction records of the St. Louis River bridge, on the Northern Pacific Railroad, at Duluth, Minn. It is not probable that any new facts have been discovered on the above-mentioned work, but there are many little details connected with pile foundations and pile bridges of considerable length that are interesting and useful to an engineer who may be engaged upon work of this character. In order that such information may be useful, it is necessary that there shall be made known the governing conditions and circumstances, which must be considered in their relations to the results of the work.

The St. Louis River, having its source in several small lakes near the northern boundary of Minnesota, after wandering about through the woods and swamps, trying all points of the compass in vain attempts to get somewhere, approaches within a few miles of the Mississippi River, and as if afraid of the prospect of traveling to the Gulf of Mexico, makes an abrupt turn eastward, and goes tumbling down over granite and sandstone ridges, till it reaches nearly the level of Lake Superior. Here it begins to loiter and spread out, covering a wide tract of country, receiving a variety of names—Spirit Lake, St. Louis Bay, Duluth Harbor, and lastly, Superior Bay. The St. Louis River Bridge crosses the St. Louis Bay from West Superior to Rice's Point, one of the divisions of Duluth.

This bridge has a total length of 5,607 feet, composed of pile-trestle and truss spans, as follows, beginning at the south end : Pile-trestle, 117 bents, 15-foot spans, 1,756 feet ; draw-span, 302 feet ; pile-trestle, 151 bents, 15-foot spans, 2,277 feet ; combination fixed span, 165 feet ; draw-span, 247 feet ; pile-trestle, 56 bents, 860 feet.

The foundations for the masonry piers are grillages of pine timber placed upon piles.

The country through which the St. Louis River flows, a succession of pine woods and tamarack swamps, conveys an idea of the material to be found at the bottom of St. Louis Bay, through which the piles were driven. Starting at the south end (the bridge lies in a north and south line), there are 400 feet of approach on shore. The soil is red clay, a depth of about seven feet with an underlying stratum of sand. From the shore the bottom slopes off quite slowly for 1,000 feet, until the depth of low water is 8 feet, the clay stratum diminishing in thickness, and disappearing, 600 feet from shore. After the depth of 8 feet of water is reached, the bottom is nearly level, a distance of 3,000 feet, to the river

channel. The underlying stratum, probably sand, is not so nearly level as the surface of the mud, if one can judge by differences of penetration of the piles. These differences would indicate that there were several ridges and hollows filled with the river sediment, decomposed vegetation mixed with clay and sand. In some places the sediment has a depth of 38 feet to 40 feet, and everywhere is very soft on top. The river channel is 350 feet wide, cut from the soft mud, giving a depth of 17 feet of water. North of the channel the mud has disappeared, and the material is sand the remaining distance to the north end of the bridge. There is very little current to the water except in the channel, and sometimes a wind from the lake drives the water up the bay.

A profile was made showing the depth reached by each bent of piles and each foundation, which gave the above information concerning the depth of mud at various points. The accompanying reduced profile, showing every seventh bent, shows the same, although not quite so plainly. This only illustrates that in driving piles, as in many other branches of engineering, the engineer does not fully know how to proceed with the work until it is finished.

The profile of the underlying bed of St. Louis Bay was a very important thing to know before ordering the 2,300 piles necessary for the structure. An approximate profile was obtained by driving test piles at intervals of about 300 feet along the centre line of the bridge. When any great difference in the driving was noticed, an intermediate pile was driven. These piles were driven from a scow, and the 300-foot spaces were measured by tying a rope to each last pile driven. The correct position of each pile was afterward ascertained by triangulation.

The records of test piles were kept as follows:

STATION.	No of pile.	Length.	Diam. top.	Diam. butt.	Depth water.	Dist. driven.	El. top pile.	El. pt. pile.	No. blows.	Fall hammer.	Wt. hammer.
80 + 23.7...	16	52′	8½″	15½″	9.7′	39.3′	84.8′	32.8′	120	20′	2,256 lbs.

PENETRATION FOR EACH 10 CONSECUTIVE BLOWS.

	13″	14″	16″	17″	15″	12″	12″
50	60	70	80	90	100	110	120

The fall given is for the last 10, 20 or 30 blows. The apparent increase of penetration in the example given between the 60th and 100th blows, was owing to the length of the pile, which permitted only a short drop of the hammer. The notes relating to the dimensions of the piles and the driving were taken at the time by the inspector; the other notes referring to the elevations were obtained afterward by the engineer. It was intended to drive each test pile until it fulfilled the requirement of the specifications, viz., "Penetration not to exceed one inch under the last blow of 2,000 pounds hammer with drop of 20 feet or equivalent."

By means of the test pile records, with the profile made from them, a list of piles for the structure was made. The list gave piles varying in length from 24 to 67 feet, and the piles were put in as at first arranged.

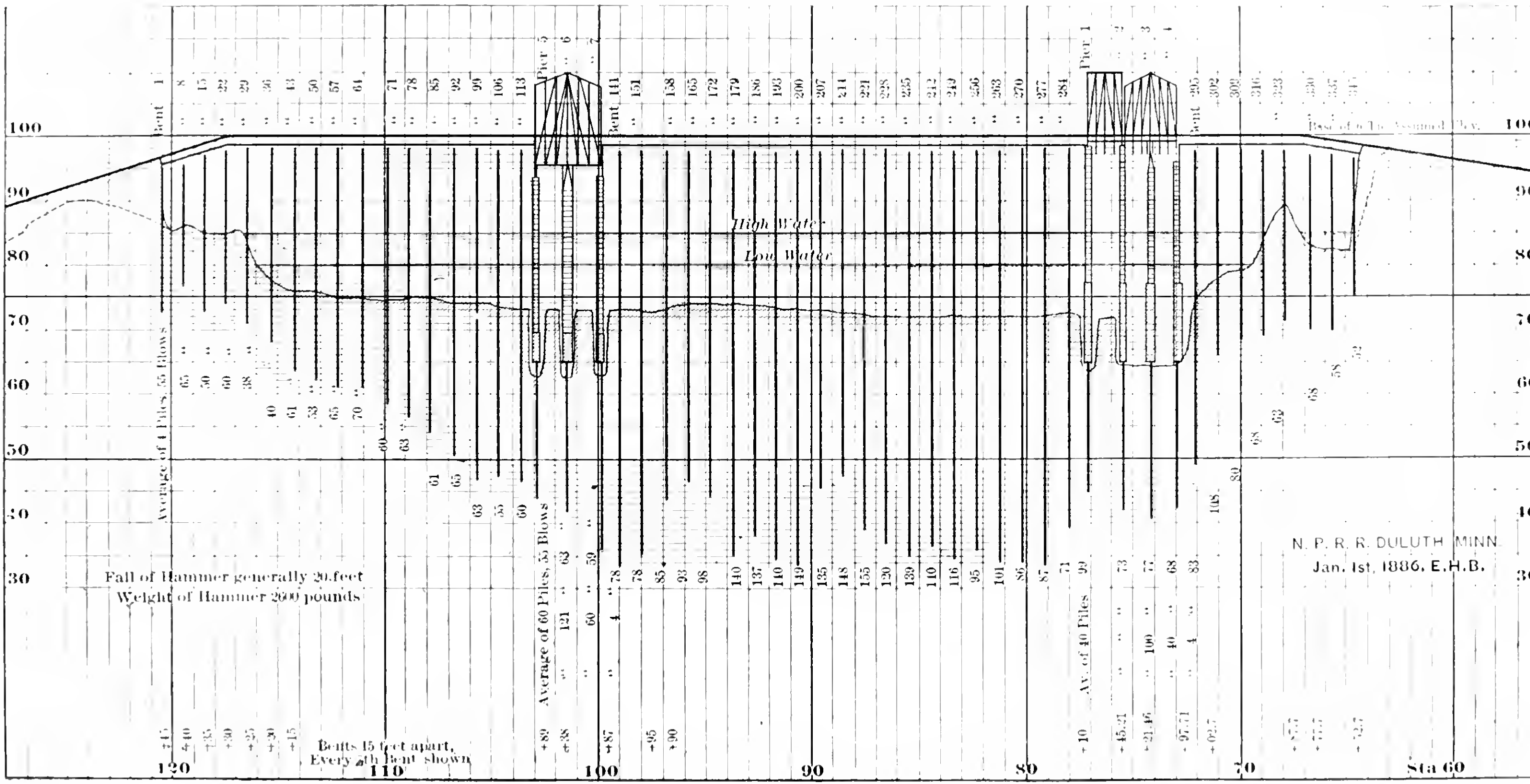
with very few alterations. It is not possible that the length of piles required could have been determined so satisfactorily by sounding or boring, and the additional information derived from the test piles, as to the number of blows, and thereby the time, was more than worth the expense.

The driving of the piles for the bridge proper began the 11th of December, 1884, after the ice was formed in the bay. By the specifications only white pine, tamarack, or oak could be used ; but owing to the difficulty of obtaining such long straight trees, Norway pine was allowed for lengths over 45 feet. No oak was furnished, and but few tamaracks. It was soon found that the Norway pine was the preferred wood, on account of not splitting. A great many days the thermometer was lower than minus 15 degrees, and it was seldom that a white pine could be driven without shattering it in such severe weather. Most white pine piles over 50 feet long that were tried had to be cut down and replaced.

At first, to prevent splitting, the head of the pile was protected by an iron follower weighing 900 pounds, which also served to hold the pile in place, the follower being made to run in the leaders like the hammer. The advantages in the use of the follower were more imaginary than real, and there was one serious objection. For holding the pile in position, yokes, staples and bars were more certain, and the apparent good condition of the pile head after driving was quite deceptive. When sawed off it was invariably seen that the blows had shaken the timber until the layers or rings were separated, and they could be removed in pieces one-half to three inches thick, leaving only a small circular core. The objection to its use was that it greatly reduced the effect of the blow. A piece of hard wood, generally elm, was placed in the top of the follower to receive the blow, and after being struck a few hundred times the fibers became separated, and the block received the blow very much like a piece of india-rubber. Also the force of each blow expended in driving the additional weight of 900 pounds, on top of the pile, was not inconsiderable. An equal number of blows upon a pile banded with a wrought-iron ring $\frac{1}{2}$ inch $\times$ $2\frac{1}{2}$ inches would show an increase of total penetration amounting to two to three feet, in each case the pile being driven until the last ten blows drove it 10 inches. This difference occurred when piles were being driven 15′ to 20′. In other words, the loss in effectiveness, due to the follower, as determined by quite a number of piles, was from one-fifth to one-sixth.

On account of the danger from piles being pulled by the ice, the experiment of driving a stick in its natural position, butt down, was tried. Two piles, driven 14 feet apart, gave results as shown in sample of records following. It was proposed at first to drive quite a number of piles in that way, but there were several good reasons for discontinuing the practice. One objection was, with piles of such great length the small amount of heart wood in the stick above water, where the top was only required to be 10 inches diameter, would lead to the decay of the piling in a very few years. The small area of the pile head receiving the blow of the hammer rendered it quite impossible to drive the piles a sufficient distance, without seriously shattering and damaging the stick. The pile drove so slowly that the number of blows required to drive it until it " brought

PROFILE OF ST. LOUIS RIVER BRIDGE.



Scales: Vertical, 1″ = 30′; Horizontal, 1″ = 900′.

up" would have increased the cost of driving fully twenty-five per cent. It is reasonable to suppose that the ice would not pull a pile driven butt down so easily as the other way, provided they were driven to the same depth. It was impossible to drive to the same depth here.

The records of driving that are usually kept are of very little use. Usually the piles are driven by contract, and often it is left to the foreman to "chock the hammer" when he thinks he has pounded the pile long enough. The penetration under a given number of blows and the total distance driven are hardly thought of, much less recorded, and to a person wishing to make a calculation upon the sustaining power, or desiring to renew the bridge, there is only matter for speculation. The possibility of this structure being injured by ice, and the probability of some renewals and changes, perhaps, for pier foundations, made it quite necessary that complete records of the driving should be kept. If no other good resulted from it, the inspector, with his time fully occupied counting blows, measuring penetrations, noting time and lengths and diameters, could feel that he was something besides "a presence."

The accompanying form of notes was kept throughout the work; the columns giving elevations were supplied by the engineer while marking the height of "cut-off" for the bridge men. A price being made for the "piles cut off," made it necessary that those lengths be recorded. Since it required no additional force in the engineering corps, and served to fully employ those necessary to the work, there is much to commend such a system and nothing to say against it.

Pile drivers were built expressly for the work, with leaders 65 feet long. The engine for raising the hammer was placed upon the driver platform and so gave it stability and reduced the labor of moving.

It was the custom to note the time when the first and last blows were struck upon each pile. With a fall of 20 feet the average was seven blows per minute. It was found quite desirable to know the time lost at all break-downs, etc., and the cause for the delay.

Those employed by contract do not generally attach sufficient importance to the fact that a short fall, 10 to 15 feet, with a heavy hammer, 2,600 pounds, will drive a pile further without injury than the long drop and light hammer. More blows are required, but not much additional time with the hammer raised by an engine.

For determining the sustaining power a sufficient variety of formulæ are to be found in "Bearing Piles," Rudolph Hering, M. A. S. C. E.

The following tables, made up from the records, will give an idea of the amount of a day's work in number of piles and lineal feet; the ratio of piles cut off to piles in structure; the number of blows required to drive, and various other points of information.

It may not be out of place to mention something of the action of the ice upon a pile bridge in such a locality. The test piles were driven in October, while the bridge was not begun until the ice had attained a thickness of two feet, and was rapidly increasing, with the temperature of the air seldom above zero for two months. It was observed during the cold weather that a contraction was taking place in the ice, causing cracks to appear, of various widths up to eight inches, aggregating about two feet. There was also a falling of the water, probably due to the

PILE-DRIVING RECORDS.

Date and station.	No. of bent.	No. of pile.	Kind of timber	Length of pile.	Diam. butt.	Diam. top.	Length below cut-off.	Length cut-off.	Elevation of ground.	Elevation of point of pile.	Distance driven.	Fall.	No of blows.	Penetrations for a given number of consecutive blows.					
Dec. 27. *114 + 30	42	1	Wh. P.	40.0′	17″	14″	31.4′	8.6′	76.2′	66.4′	9.8′	20′	85	20	10″ 40	10″ 60	5″ 70	4′ 80	1″ 85
†114 + 30	42	4	Wh. P.	40.0′	16″	11″	33.0′	7.0′	76.2′	64.8′	11.3′	20′	60	20	10″ 30	7″ 40	7″ 50	7″ 60	....
‡Jan. 10. 112 + 65	53	3	Wh. P.	42 0′	15″	13″	36.0′	6.0′	74.8′	61.8′	13 0′	18′	50	...	....	20	11″ 30	11″ 40	9″ 50
§	....	4	....	41 0′	17″	11″	37.3′	3.7′	74.8′	60.4′	14.3′	18′	50	....	....	20	13″ 30	10″ 40	8″ 50
Feb. 4.	183	1	Nor. P	67.0′	18″	11″	65.6′	1.4′	73.9′	32.2′	41.7′	20′	138	100	48″ 110	38″ 120	30″ 130	24″ 138	....
	...	2	Nor P.	67.0′	18″	10″	66.0′	1.0′	....	31.8′	42.2′	20′	148	....	36″ 110	40″ 120	38″ 130	28″ 140	20″ 148
93 + 15	....	3	Nor P.	67 0′	20″	13″	64 9′	2.1′	....	32.8′	41.1′	20′	150	....	40″ 110	38″ 120	36″ 130	35″ 140	**35″** 150
	....	4	Nor P.	67.0′	20″	12″	65.3′	1.7	....	32.4′	41.5′	20′	140	....	40″ 110	26″ 120	30″ 130	30″ 140	....
Jan. 20.	135	1	Nor. P.	60.0′	17″	11″	57.7′	2.3′	72.6′	40.1′	32.5′	18′	65	...	25	22″ 35	17″ 45	15″ 55	10″ 65
100 + 35	....	2	Nor. P.	62.0′	19″	13″	59 5′	2.5′	....	38.3′	34.3′	18′	65	....	....	16″ 35	15″ 45	13″ 55	8″ 65
	....	3	Nor. P.	60.0′	19″	13″	57 3′	2.7′	...	40.4′	32.2′	18′	55	....	....	19″ 35	15″ 45	10″ 55	....
	...	4	Nor. P.	60.0′	18″	13″	57.1′	2.9	...	40.7′	31.9′	18′	65	....	...	14″ 35	13″ 45	12″ 55	10″ 65

* This pile was driven butt down. † Driven in the usual way. ‡ Driven with Follower. § Driven without Follower. NOTE.—Weight of hammer, 2,600 lbs.

westerly wind, which is common with the cold weather about Lake Superior in winter. The test piles were somewhat inclined, and moved up stream with the shifting ice.

A rising temperature, with an easterly wind from off the lake, driving back the water, lifted the ice and closed the cracks and threw up a ridge two or three feet high, nearly parallel to the bridge line. Another cold snap coming on, the same action, as above described, was repeated. It was found that nearly all the test piles were broken off (some feet below the ground surface, where the material was soft at the top), and the broken portions were raised by the ice. Two, and perhaps three, piles, which were 38 to 40 feet in mud, were raised whole. The pointed ends of two were finally brought above the ice, by other means, after the ice had raised them 10 or 12 feet in about six weeks. The water surface sometimes changed, in elevation, 0.5 foot in an hour.

Some bents of piles capped, but not braced, were swayed badly out of line, and inclined longitudinally. In times of considerable ice action, centres on the completed structure showed a lateral deviation of 0.15 foot.

After the ice surface had received a covering of snow, there was less action. The ice attained a thickness of 4 feet in many places along the bridge. There appears to be little or no danger from pulling, but the combined strength of four piles in each bent may be severely tried in resisting the lateral pressure.

The most trying (the early) portion of another winter has now passed (Jan. 1), and no harm has been done to the structure.

SUMMARY OF WORK OF ONE DRIVER.

Dates.	No. of days.	No. of piles driven.	Lineal feet of piles driven.	No. of piles driven daily.	Lineal feet of piles driven daily.	* Contractor's cost of driving	Average cost of driving per lin. ft.
1884.							
Piles from 23′ to 45′ long.							
Dec. 11 to 31	10½	202	6,520½	19¼	621	$454.43	$0.06969†
Jan. 1 to 5 and 10 to 14	5¾	134	5,785	23 3-10	1,006	212.57	0.0367
Piles over 45′ long.							
Jan. 5 to 10 and 14 to 31	14½	364	21,535	‡25 1-10	1,485	539.61	0.02506
Feb, 1 to 28	19¾	379	25,036	19 1-5	1,268	747.74	0.0298
Mar. 1 to 5	3¼	73	4,789	22½	1,473	135.75	0.0284

Average cost per lineal foot, piles less than 45 feet long	$0.0542
" " " " " " over " " "	0.0277

* Contractors, Winston Bros. of Minneapolis. Actual cost of driving after the piles were delivered at the pile-driver.

† Some delay on shore by frozen ground.

‡ The best record was 120 piles = 6,600 feet in 4 consecutive days.

TOTAL PILING USED IN STRUCTURE.

	Number.	Lineal feet.	Average length.
Piles less than 51′ long	1,197	50,758	
" from 51′ to 60′ "	595	33,104	
" " 60′ to 70′ "	547	36,248	
Total	2,339	120,110	51.3

DISTRIBUTION.

	Number of piles.	Total length.	Length below cut-off.	Length cut-off.	Average cut-off.
Pile bridging	1,376	71,607	64,782	6,825	4.96
Foundations, 7 piers	461	21,787	11,001	10,786	23.39
Draw protections	316	15,999	14,815	1,184	2.44
Temporary bridge	120	7,002	6,699	303	2.53
Other temporary work	66	3 715			
	2,339	120,110			

NOTE.—Length of cut-off in pile bridging was considerably increased by the cold weather. With temperature from zero to – 30°, piles began to split before being fully driven.

In foundations deduct 20′ from cut-off to bring head of pile above water.

In draw protections "average cut-off" shows omission of 18 piles, which were cut off under water.

CREMATION OF GARBAGE.

By John Zellweger, Member of the Western Society of Engineers.

[Read February 2, 1886.]

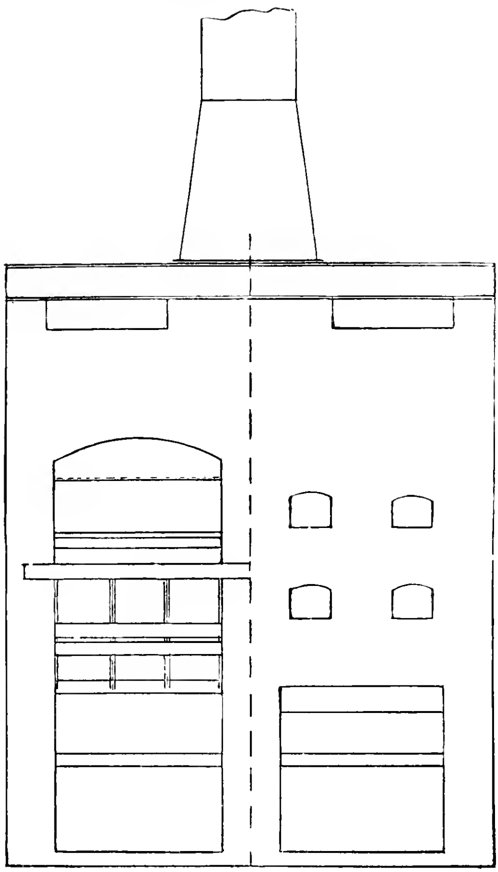
Garbage comprises household and market refuse and consists of organic and inorganic matter in varying proportions according to the season. The organic matter is of vegetable or animal origin and the inorganic consists principally of ashes and water. Under the influence of the atmosphere, of moisture and of heat, garbage is subject to decay, and then becomes a source of danger to our health; its prompt disposal is therefore an important factor in the care for public health.

Garbage is disposed of either by simple removal by teams and cars to points outside of cities and towns, and there used as manure or as filling and left to itself, or it is collected at stations within the cities and there destroyed by heat as fast as it accumulates, and the ashes used as filling for streets, etc.

The destruction of the organic portion of garbage is based upon the decomposing effect of heat on the combination of elements contained therein, and upon the affinity of some of these elements for oxygen. The process of destruction is effected in an apparatus designed to expose the charge and the gases emanating therefrom to a high heat and to the contact of hot air. The heat required for this purpose is produced by combustion of garbage with or without additional fuel. For the sake of economy, it is desirable that the process of destruction be self-sustaining—that is, that the heat required be produced by the combustion of the carbon and hydrogen in the organic compounds and in the coke in the ashes.

The problem of destroying garbage by heat, therefore, involves the construction and operation of a furnace that will completely and economically burn great quantities of a fuel containing a large percentage of ashes and water. The capacity of a garbage furnace and the economy of its operation are greatly dependent upon the quantity of an organic

admixture to the fuel, and it is therefore indicated either to collect the organic matter as much as possible free from ashes and non-fuel, or to separate it from them by means of screens before charging into the furnace. Water and other liquids should be drained out of the garbage intended for cremation, and can be conveyed under the grate of the furnace, there vaporized and passed through the incandescent fuel for



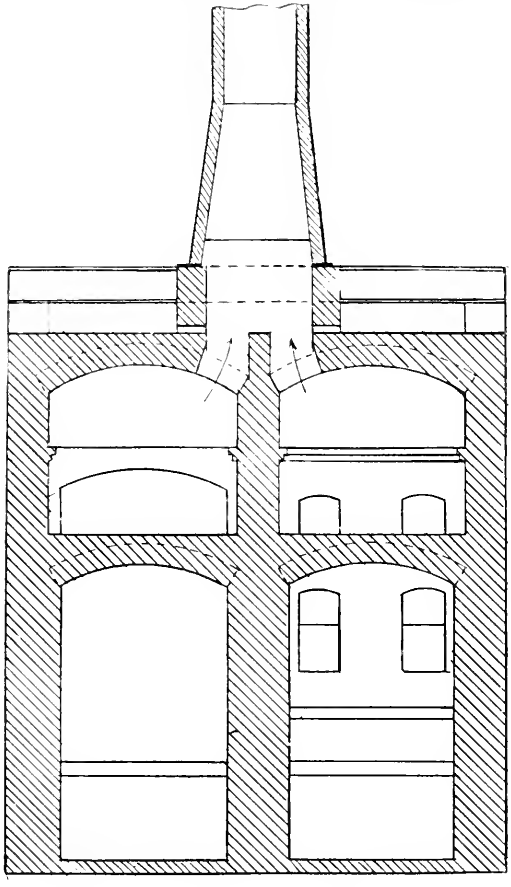
END VIEWS

decomposition. Garbage cannot be completely destroyed by direct charging and burning on an ordinary grate without an excessive use of additional fuel; it requires a systematic treatment and a furnace adapted to the same. The cremation of garbage consists of several distinct processes, which may be classified as follows:

1. The drying of the fresh charge.
2. The destructive distillation of the dry matter.
3. The burning of the remaining charcoal and coke.

4. The decomposition and oxidation of the organic vapors and gases produced in drying and charring the garbage.

These several processes must be carried on separately and in different parts of the furnace, so that the consumption of heat does not interfere with its production. It is essential for the successful cremation of garbage that the full calorific power of the fuel be developed, and all the

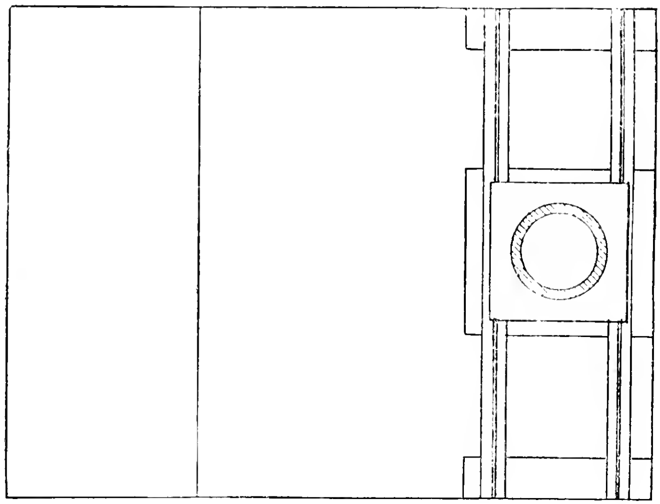


CROSS SECTION

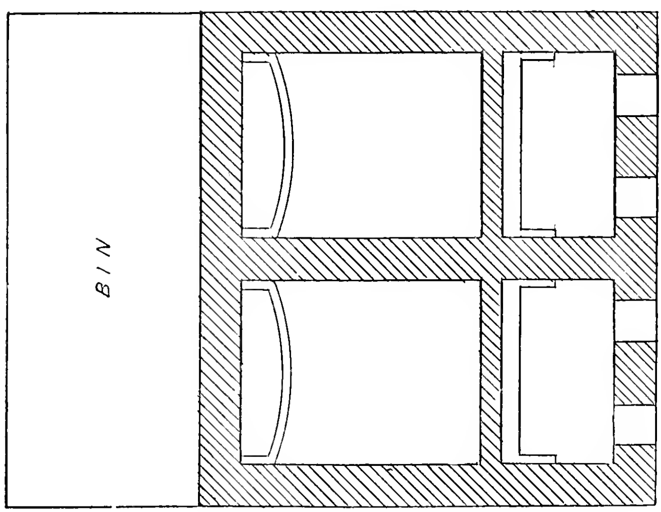
available heat be transferred to the fire gases before these are allowed to mingle with the aqueous vapors and organic gases rising from the fresh charges in the furnace. The heat produced by the combustion of charcoal, coke and the gases expelled by destructive distillation is then brought to act upon the gases mingled with and protected by steam, to decompose them and to cause their oxidation in the accompanying air.

The accompanying drawings represent a battery of two garbage furnaces, each of 7 tons capacity for 24 hours. The garbage is to be hauled

on top of the furnaces by wagon and deposited in an iron bin, where it can drain itself of water; from this bin it slides by gravity on to a *solid* inclined plane in the furnace, and is here exposed to radiant heat from a



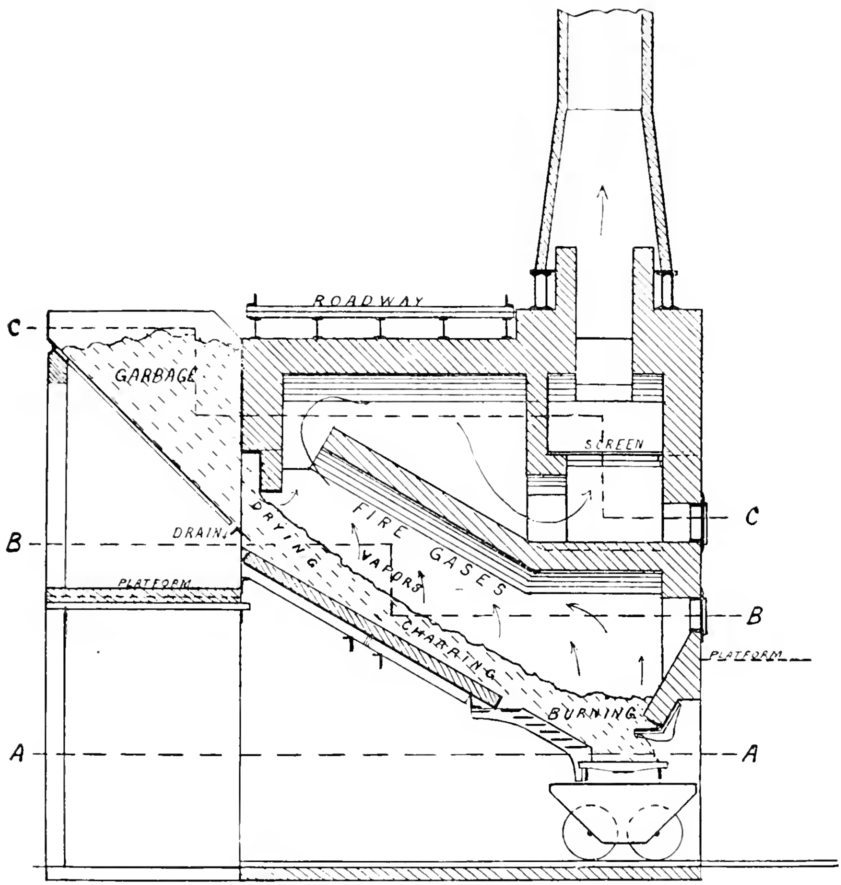
TOP VIEW



SECTION "C-C"

hot brick arch above it, and to the contact of hot fire gases passing over it. When by the action of heat and ventilation the material has become dry, it is pushed down the inclined plane and replaced by a fresh charge. The garbage, on descending the inclined plane, is exposed to higher

degrees of heat, and undergoes destructive distillation, the charcoal formed is pushed on to the step grate at the foot of the inclined plane, where it commences to burn, and is finally consumed on the level grate in the bottom of the furnace chamber. The gases expelled by heat from the dried garbage on the inclined plane ignite with the free oxygen of the surplus air admitted through the grates. The hot fire gases then mingle

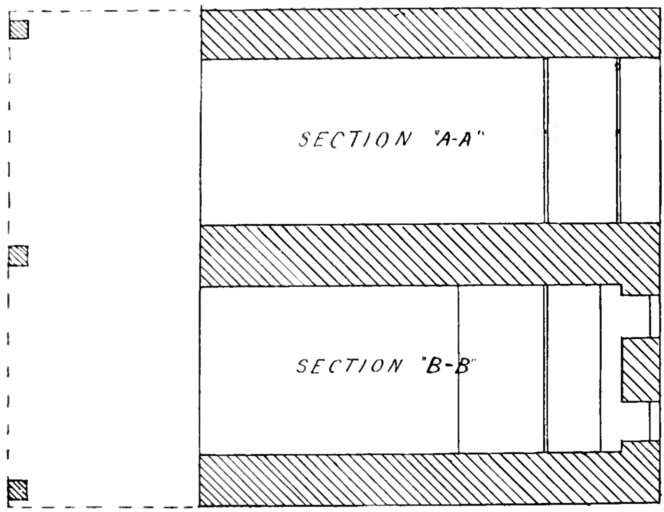


LONGITUDINAL SECTION

with the aqueous vapors rising from the fresh charges, and on their way through a secondary fire-room above the furnace chamber decompose the organic gases that may be contained in those vapors. Should the heat produced by the combustion of garbage alone not be sufficient, it becomes necessary to spread fine coal (screenings) over the fire through the two doors in the rear of the furnace. Ashes and clinkers found on the grate are pushed directly into suitable wagons placed underneath it.

Back of the fire-room and above the furnace chamber is a dust chamber, accessible through two doors, and above this chamber is the chimney flue, provided with a damper for each furnace. The chimney is a brick-lined iron tube, set on top of the furnaces, and stayed sideways.

Assuming that the garbage is deposited in the bin by the scavengers who collected it, and that the ashes and clinkers are hauled off by the same men, it takes but one man to attend to two furnaces, causing an expense of 21 cents per ton of garbage destroyed if no coal is used, and of 36 cents per ton of garbage if 1 ton of screenings is used in each fur-



nace for 24 hours. Since garbage as a rule does not require additional fuel for its destruction the average cost of the process will not exceed 25 cents per ton. Among the special advantages afforded by a garbage furnace is the possibility of effectively destroying matter that can not otherwise be well disposed of, such as infected articles, dead animals, etc. For the destruction of large quantities of garbage the necessary furnace capacity may be provided for either at several separated stations to save haulage, or at one central station to facilitate management and attendance : in the latter case all the furnaces may be connected to one common chimney of large dimensions.

THE WORK OF THE UNITED STATES TESTING MACHINE AT WATERTOWN ARSENAL, MASS.

By J. E. Howard, Engineer in Charge of Testing Machine at Watertown Arsenal.

[Remarks made at Dinner of Boston Society Civil Engineers, March 17, 1886.]

There are three classes under which the tests made at Watertown Arsenal may be considered :

1. Tests made for the Ordnance Department and other departments of the Government.
2. Tests made for private parties.
3. Industrial tests.

The first class includes those tests made on the physical properties of all material used for ordnance construction and the experimental elucidation of those problems associated with gun work.

The second class of tests are made for engineers, manufacturers and consumers of structural material, and relate to the quality of the metal examined in the sample bar and in full-sized members. The results of these tests are made known only to the parties on whose account the work is done. All other tests are reported annually to Congress and published as a public document.

The industrial tests comprise both an examination of the qualities of the metals and their strength in various combinations, also the development of the principles and laws which govern the strength of complicated structures.

The principal lines of investigation being carried on are some extensive tests of bridge columns ; riveted joints in both iron and steel plate ; material subjected to long-continued service ; brick piers ; wooden columns : tests of hot bars of wrought iron, cast iron and steel.

Referring briefly to the industrial tests, the following results may be mentioned as embodying certain facts more or less at variance with generally accepted notions on the strength of materials.

The column tests have shown the resistance of ordinary forms of built posts in different cross-section dimensions and lengths.

The tendency of compression tests is toward that improvement in design and workmanship by which a resistance equal to the elastic limit of the material is reached, whether the column be longer or shorter.

The manner of failure indicates a practical limit to columns in terms of their diameters, long posts failing by sudden springing after the deflection has reached a small amount, at once reducing the resistance 40 per cent. or more ; whereas, with shorter posts there is no sudden loss in strength: the deflection takes place gradually with a gradual reduction in resistance.

In the tests of riveted joints their behavior is observed and micrometer readings taken on the specimens from the first loads up to the time of rupture.

Generally speaking, the efficiency of joints in steel plates has been found higher than in iron; a joint of the former metal was tested which gave 90 per cent., the strength of the solid sheet.

It is inferred from a comparison of the behavior of joints and the solid metal, that in steam boiler practice it would be desirable to arrange the longitudinal seams of a cylindrical boiler nearly in lines from end to end, and not break joints in the different courses of sheets, as commonly done.

The comparative influence of punched and drilled holes on the strength of the metal is shown to depend upon the proportions of the test pieces. Numerous instances have been met in which the punched plates exceeded in strength the drilled plates. Punching produces an effect analogous to cold swaging or cold rolling, well-known methods for elevating the tensile strength. In a joint with close pitched holes the effect of the punching is felt across the net section of the plate, and the result is increased tenacity; but in wide pitched holes there is a disadvantage in having hard metal at the holes by increasing the tendency to fracture in detail. Notwithstanding the greater strength in certain plates with punched holes over drilled ones, the drilled holes are generally to be preferred on account of leaving the ductility of the metal unimpaired.

Some locomotive parallel and main driving rods have been examined after 37 years' service, and having run 900,000 miles, and the metal found tough and fibrous, comparing favorably in tensile strength with good iron of to-day.

A series of tests with trader axles are in progress. Tests of the metal after 95,000 miles run show no change in its tensile properties. Observations made on the axles in place with the trader fully loaded, gave deflections which corresponded to a maximum fibre strain of about 14,500 pounds per square inch, which is alternately one of tension and compression, making the total range of stress 29,000 pounds per square inch.

A number of bars of extra and double refined iron, which were fibrous in their fractures when first tested, have shown, when re-tested after different periods of rest, a gradual development of brittleness, until now, after a period of about four years, the fractures are almost wholly granular, with very little contraction in area. The tensile strength, in the mean time, has increased from 50,000 to upward of 60,000 pounds per square inch. Annealing restores the metal to its original fibrous structure as shown in the fracture, also to its original tensile strength. This illustrates the wisdom of annealing chains after long use. On the other hand, some wrought-iron boiler plate, re-tested after three years' rest, was found to retain its primitive fibrous, lamellar structure.

Brick piers have been tested in sizes ranging from 8 inches to 16 inches square, and up to 10 feet in height, and laid in different kinds of mortar.

The moduli of elasticity of individual bricks, of the various kinds of mortar, and of the piers themselves, were determined. The difference in behavior of the mortar and bricks under compressive stress is sufficient to account for cracks in brick-work under certain pressures without attributing them to defective foundations. Common brick piers laid in lime mortar were found to have about 14 per cent. additional strength when

joints were broken once in six courses over the ordinary method of breaking joints with each course. Laying the bricks on edge was found to increase the strength of the piers about the same amount.

Some observations on steel and wrought-iron bars show a reduction in the modulus of elasticity, resulting from straining the metal beyond its primative elastic limit. In this way the modulus of elasticity of a steel bar was reduced from 29,000,000 lbs. to 17,000,000 lbs. Rest restores the modulus to its original value, the wrought-iron bars displaying an ability to thus recuperate earlier than the steel. The full significance of this remarkable change is yet a matter of conjecture, but suggests the probability of its being the result of a molecular disturbance affecting the durability of the metal.

Preliminary tests have shown that bars of wrought iron at the so-called "critical" temperature or blue heat possess a tensile strength greatly in excess over the cold bar, the stresses being gradually applied and in direct line with the axis of the test piece.

Samples of different metals have been subjected to an hydrostatic pressure of 90,000 pounds per square inch, and afterward tested by tension, without showing any change in their strength or ductility. In cold-rolled metal we have illustrated the effect of pressure accompanied by flow, which elevates both the elastic limit and the tensile strength. In these cubic compressed specimens pressure without flow is shown to produce no effect on the tensile properties.

While making these tests, the compressibility of water, carefully boiled to expel the air, under high pressure was found to be considerable. The leather packings employed to seal the water in the hydrostatic cylinder during these tests worked well under a pressure of 117,000 pounds per square inch.

The testing machine is now worked to its full capacity, and there is an accumulation of work ahead. The Ordnance Department, U. S. A., has taken active steps toward procuring additional testing machinery to meet the increased demands of this work, and which will enable the large machine to be employed wholly on the tests of full-sized members, the smaller machines testing the smaller samples, thereby materially increasing the efficiency of the testing laboratory.

NOTE.

In the paper on the Worcester Sewerage Tunnel, printed in the JOURNAL, Vol. V., No. 5, page 147, the author omitted to state that the entire work was in charge of Charles A. Allen, City Engineer of Worcester, and was done by the Sewer Department, under the immediate direction of General Robert H. Chamberlain, Superintendent of Sewers, assisted by Mr. Richard Forbes, C. E., Assistant Engineer in charge of sewer construction.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

REPORT OF THE COMMITTEE ON WEIGHTS AND MEASURES.

[Read March 3, 1886.]

To the Boston Society of Civil Engineers:

Your Committee on Weights and Measures respectfully presents the following report:

This Society has had, for quite a number of years, a committee designated as the "Committee on the Metric System of Weights and Measures." Originally appointed to consider and report upon the introduction and use of the *metric system*, it was required, several years ago, to report also upon other systems of weights and measures. When the question as to the continuance of this committee came up last year, it was decided not to have a committee upon any specific system, but rather to have a committee upon the general subject of weights and measures. Notwithstanding this apparent enlargement of the scope of the subject, your committee finds that the metric system occupies an exceedingly prominent position among weights and measures, and that a very large portion of this report must be devoted to its consideration.

A Prime Meridian and a Universal Day.

In pursuance of an Act of Congress, approved August 3, 1882, and entitled "An Act to authorize the President of the United States to call an International Conference to fix on and recommend for universal adoption a common prime meridian, to be used in the reckoning of longitude and in the regulation of time throughout the world," the President caused invitations to be sent to the Governments of nations in diplomatic relations with our own, to appoint delegates (not exceeding three from any nation) to meet delegates from the United States and other nations in an international conference, to be held in the city of Washington on the first day of October, 1884.

The following Governments were represented at this conference: Austro-Hungary, Brazil, Chili, Colombia, Costa Rica, France, Germany, Great Britain, Guatemala, Hawaii, Italy, Japan, Liberia, Mexico, Netherlands, Paraguay, Russia, San Domingo, Salvador, Spain, Sweden, Switzerland, Turkey, the United States, Venezuela.

The Conference held eight sessions, during which the subjects submitted to it were thoroughly discussed, and adjourned *sine die*, Nov. 1, 1884. The resolutions adopted by the Conference, "after careful and patient discussion," are as follows:

1. "That it is the opinion of this Congress that it is desirable to adopt a single prime meridian for all nations, in place of the multiplicity of initial meridians which now exist." Adopted unanimously.

2. "That the Conference proposes to the Governments here represented the adoption of the meridian passing through the centre of the transit instrument at the Observatory of Greenwich, as the initial meridian for longitude." Adopted by the following vote: Ayes, 22 nations; noes, 1; abstaining, 2.

3. "That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus." Adopted by the following vote: Ayes, 14 nations; noes, 5; abstaining, 6.

4. "That the Conference proposes the adoption of a universal day for all pur-

poses for which it may be found convenient, and which shall not interfere with the use of local or other standard time where desirable." Adopted by the following vote: Ayes, 23 nations; abstaining, 2.

5. "That this universal day is to be a mean solar day; is to begin for all the world at the moment of mean midnight of the initial meridian, coinciding with the beginning of the civil day and date of that meridian, and is to be counted from zero up to twenty-four hours." Adopted by the following vote: Ayes, 15 nations; noes, 2; abstaining, 7.

6. "That the Conference expresses the hope that as soon as may be practicable, the astronomical and nautical days will be arranged everywhere to begin at mean midnight." Carried without division.

7. "That the Conference expresses the hope that the technical studies designed to regulate and extend the application of the decimal system to the division of angular space and of time shall be resumed, so as to permit the extension of this application to all cases in which it presents real advantages." Adopted by the following vote: Ayes, 21; abstaining, 3.

It was also resolved unanimously: "That a copy of the resolutions passed by this Conference shall be communicated to the Government of the United States of America, at whose instance and within whose territory the Conference has been convened."

The seventh resolution was introduced by the Delegate of France, M. Janssen, with some interesting statements from which the following is quoted:

"You are aware, gentlemen, that at the time of the establishment of the metrical system the decimal division had been extended to the measurement of angular space and to time. Numerous instruments were even made according to the new system. As to time, the reform was introduced too abruptly, and, we might say, without enough discretion, and it came into conflict with old habits and was quickly abandoned; but as to the division of angular space, in which the decimal division presented many advantages, the reform sustained itself much better, and is still used for certain purposes. So, the division of the circumference into 400 parts was adopted by Laplace, and we find it constantly employed in the Mécanique Céleste. Delambre and Méchain used, for the measurement of the arc of the meridian from which the meter was derived, repeating circles divided into '*grades*.' Finally, in our own time, Colonel Perrier, Chief of the Geographical Division of our Department of War, has used instruments decimally divided, and at the present time logarithmic tables appropriate to that method of division are in course of calculation."

"But it is especially when it is a question of making long calculations of angular space that the decimal system presents great advantages. In this respect we find, so to speak, only one opinion expressed by scientists."

"The Conference at Rome, which brought together so many astronomers, geodetists, eminent topographers—that is to say, the men most competent and most interested in the question—expressed in respect to it a desire, the high authority of which it is impossible to mistake."

"It is, therefore, now evident that the decimal system, which has already done such good service in the measurement of length, volume and weight, is called upon to render analogous services in the domain of angular dimensions and of time." * * *

"I think that the character of the reform would be well defined by saying that it is intended especially to make a new effort toward the application of the decimal system in scientific matters."

The Metric System of Weights and Measures.

The most important fact to be noticed in connection with the metric system is the adhesion of Great Britain to the Metric Convention of May 20, 1875. This Convention was a treaty signed by sixteen States of the Old and New Worlds, by

which it was stipulated that provision for the institution and maintenance of an International Bureau of Weights and Measures should be made by appropriations *pro rata* from the different assenting nations.

"The principal aim of this institution has been to create and to perpetuate for all these States a true unit of metric weight and measure by furnishing to them prototypes, as nearly as possible unalterable, identical in material and in construction, and whose equations should be rigorously established with reference to international prototypes of the meter and of the kilogram previously to be intrusted to the International Bureau, and differing as to length and to weight as little as possible from the old prototypes of the archives of France."

"Consequently, the Bureau was charged by the Convention:

"To execute all comparisons and verifications of the new prototypes of the meter and kilogram.

"To compare periodically the national standards with the international prototypes.

"To establish the equations of the ancient normal standards employed in different countries, with reference to the new metric prototypes.

"To seal and to compare geodetic rules which have been used, or shall be used, in measuring the bases for the triangulations of different countries; and, finally,

"To compare standards and scales of precision, the verification of which should be requested either by Governments, by scientific societies, or by scientists and artisans."

Of the sixteen States that originally signed this Convention, nine had already made the use of the metric system obligatory; five, among whom was the United States, had legally rendered its use optional, and the remainder had taken no steps toward its introduction.

Great Britain had at this period already rendered the use of the metric system permissive, and was in this respect in precisely the same condition as was this country. The British Government, however, with characteristic conservatism, declined to take part in the Convention and contribute toward the support of an institution established to promote the ultimate unification of the weights and measures of the world.

Before many years had elapsed, the British Standards Department twice found it necessary to request permission to avail themselves of the refined instruments and processes of the International Bureau. This was permitted as a matter of courtesy.

In April, 1884, the British Standards Department having asked the favor for the third time, and having expressed itself ready to pay the cost of the comparisons to the amount of 2,000 francs, the International Bureau politely declined, for the following reasons:

* * * "Although, on two occasions, the committee has thought it ought to yield to the request of the British Government for permission to compare standards at the International Bureau, it was merely as a matter of courtesy, with the hope of thus convincing the British Government of the value of the services which the International Bureau could render it, and thus cause it to decide to join the Convention, on equal terms with many other civilized countries, among whom are not only several States where, as in England, the metric system is permissive, but also several, as Russia and Denmark, which have not as yet introduced it."

"The committee has not thought that Great Britain would wish to profit indefinitely from the services of an international establishment, without contributing toward its support in the same manner and, proportionately, by the same sacrifices as the States which founded it."

"On the other hand, although the Committee, in pursuance of article 6 of the Metric Convention, has just opened the International Bureau for the verification of standards and scales of precision, asked by Governments, by learned societies, or

even by artisans and scientists, this measure, taken in the interests of the development of the sciences and of the precise arts, only applies to private standards, and not at all to the official weights and measures belonging to the Government of a State that has not as yet joined the Convention." * * *

This correspondence, together with certain unofficial advances made by members of the International Committee toward the Astronomer Royal and toward Mr. Gill, the director of the observatory of the Cape of Good Hope, who was then in Europe, led to the active intervention of the Royal Society in favor of the adhesion of England.

This patronage of the highest scientific authority of England has succeeded in convincing Her Majesty's Government of the utility of the participation of England in the work of the International Bureau, and the British Government authorized the President and Council of the Royal Society to officially notify the International Committee that the Government would be ready to adhere to the Convention under certain specified conditions. These conditions, as expressed in the letter of the Secretary of the Royal Society, were "that Her Majesty's Government desire to guard themselves in the most explicit and formal manner from the admission, by their proposal to join the Bureau, of any intention of adopting or proposing the adoption of the metric system in this country."

In the reply of the President of the International Committee, these conditions were accepted in the following language:

"* * * As to the conditions specified by Her Majesty's Government, concerning which it does not become us to consider in this connection either the motive or the consequences for the progress of science, manufactures and commerce, we can but affirm that there is no article of the Metric Convention or of the appended regulations, implying any obligation to modify the legal condition of weights and measures in the contracting States. Adhesion to the Convention leaves absolutely intact the liberty of the States as to internal legislation on weights and measures, and implies in no way for Great Britain the necessity of introducing the obligatory use of the metric system in that country. In this connection, we wish to remark that there are already among the contracting States not only several in which the metric system is permissive, but also some in which the metric weights and measures are not yet legally introduced."

The official notice of the adhesion of Great Britain to the Metric Convention was received by the International Committee in September, 1884.

This action of the British Government indicates the spread of liberal ideas and the increasing influence of scientific men. No change whatever has been made in the terms of the Metric Convention nor in the object of the International Bureau, whose principal aim is "to create and to perpetuate for all these States a true unit of metric weight and measure." These remain to-day the same as they were in 1875, when Great Britain refused to recommend to Parliament "any expenditure connected with the metric system, which is not legalized in this country, nor in support of a permanent institution established in a foreign country for its encouragement:" yet to-day we find Great Britain in the list of the contracting States.

We have here the record of another step toward the unification of diverse standards, and the adoption of an international system of weights and measures. Public opinion in England favoring the metric system will gradually become stronger than Government inertia. That the opinion of scientific men is already strongly in favor of that system, is shown by the brief remarks of Sir William Thompson before the International Meridian Conference at Washington in October, 1884.

He said: "I sympathize deeply with what has been said in regard to a common metrical system. I have a very strong opinion upon this subject, which I will not express, however, if it meets any objection from the Chair; but it seems to me that England is making a sacrifice in not adopting the metrical system."

The nature of this sacrifice may be gathered from the following quotation from a letter of Mr. C. L. Hett, in the discussion of a paper on British and metric measures before the Institution of Civil Engineers in London in January, 1885. "Although this subject had been thoroughly discussed years ago, it was under very different conditions to those which now prevailed. At that time there was hardly a competitor with England in the foreign trade. The British were virtually in a position to dictate to countries employing the metric system, and to say, 'There is our machinery, made to our measurements, and without the slightest consideration of your convenience.' But now it was different ; there were makers from countries employing the metric system ready to supply any order for machinery, and year by year the excellence of their goods would be improved until their workmanship was equal to our own, and our last advantage over them would be gone. It was sometimes urged that if the United States did not adopt the metric system, why should England ? The Americans were agitating for its adoption ; and the first country to change would have a great advantage in trading with those other nations who had already adopted it." * * * "The feeling that the metric system must sooner or later be adopted was not confined to engineers and scientific men: it was shown by the action of the Leicestershire Chamber of Agriculture in 1878, which opposed the legalization of the cental on the ground that it might impede the adoption of metric rights and measures."

This paper and discussion have been reprinted in some recent numbers of *Van Nostrand's Magazine.*

The following table gives a list of the nations contributing to the support of the International Bureau of Weights and Measures, their population, and the amount due from each for the year 1885 :

Contracting States.	Population.	Co-efficient.	Proportional part.	Assessment for 1885.
				Francs.
1. Germany	45,194,172	3	136	14,286
2a. Austria	20,136,283	3	60	6,303
2b. Hungary	15,508,573	3	47	4,937
3. Belgium	5,635,452	3	17	1,786
4. Argentine Confederation	2,000,000	3	6	630
5. Denmark	1,980,675	1	2	210
6. Spain	24,456,468	3	73	7,668
7. United States of America	50,000,000	2	100	10,504
8. France	42,403,892	3	127	13,340
9. Great Britain and Ireland	35,172,976	2	70	7,353
10. Italy	28,209,620	3	85	8,929
11. Peru	2,699,945	3	8	840
12. Portugal	5,400,000	3	16	1,681
13. Roumania	5,000,000	3	15	1,576
14. Russia	93,144,454	1	93	9,769
15. Servia	1,600,000	3	5	525
16a. Sweden	4,577,783	2	9	945
16b. Norway	1,900,000	3	6	630
17. Switzerland	2,831,787	3	8	840
18. Turkey	32,024,000	2	64	6,723
19. Venezuela	1,784,194	3	5	525
Total	421,660,274		952	100,000

The proportional part of the total, 100,000 francs, which is assessed each nation, is determined by multiplying the number of population, in millions, by the co-efficient 3, for nations in which the metric system is obligatory; by 2, for nations in which the metric system is permissive; and by 1, for nations in which the metric system is not yet legally introduced.

The adoption of the metric units as the basis of electrical measurements was mentioned in the last report of your Committee on the Metric System. This method of measuring is becoming the standard wherever electrical science prevails.

The introduction of the metric system into Germany was begun many years ago. The decree of August 17, 1868, by which the metric system was adopted in Germany, permitted the use of a number of old German names in connection with metric weights and measures, and allowed the use of the *schoppen* (½ liter), the *scheffel* (50 liters) as units of capacity, and the half-kilogram and fifty-kilogram weights as units, under the names *pfund* and *centner*. This retention of old names and irregular units approximately representing the old weights and measures, was expected to diminish the cost and difficulty of the transition to the metric system.

During the twelve or fourteen years of active use of the metric system in Germany, the concurrent use of the *pfund* series of weights based on the *half-kilogram*, and the *metric* series of weights based on the *kilogram*, was found to be the source of endless confusion and error. After the adoption of the metric system, the customs of trade gradually changed to conform to the new units. Wholesale trade adapted itself completely to the *kilogram* system. In the governmental services of the customs, assessors' department, post-office, railways and statistics, the *pfund* unit has been out of use for a long time. It is also disappearing from the arithmetics prescribed for school use.

In retail trade only has the *pfund* series been retained, as a convenience to those who had grown up with the old system of weights. The rapid and uninterrupted introduction of the imperial monetary system without any preparatory stages, and the favorable experience in Austro-Hungary, where the *kilogram* unit was introduced without any preparatory use of a half-unit, led to the expectation that retail trade would readily adapt itself to the *kilogram* whenever the *pfund* unit should be legally set aside.

This has been accomplished by the law passed by the German Reichstag in May, 1884, which amends the decree of August 17, 1868, abolishing the use of the *pfund*, its subdivisions and multiples, including the *centner*, and the use of the *schoppen* (½ liter) and the *scheffel* (50 liters) as units of capacity. It also discontinues the use of the dekameter, or *chain*, the dekagram, or *neuloth*, the decigram and the centigram as units. These, although belonging to the metric series, are seldom used as units. They occupy positions analogous to those of the *eagle* and *dime* in our monetary system. When used as units, they may cause confusion of the same nature as that caused by stating a value in eagles or dimes, instead of in dollars or cents.

In the bill, the German names of the weights and measures have been discarded; it being well known that trade has never availed itself of the terms "*stab*," "*neuzoll*," "*strich*," "*kette*," "*kanne*," "*schoppen*," "*fass*," "*neuloth*," as indicating metric units of measure or weight.

The lesson taught by this experience in Germany is that the change from one system of weights and measures to another should be complete and thorough; that it should be done by one step and not by means of preparatory stages; that the retention of old names and irregular units approximately representing old weights and measures leads to confusion and error, and prolongs the trouble, cost and duration of the transition to the new system.

In the British mint the decimal method of expressing the composition of ingots has been recently introduced, and metric expressions have been used. By the

ancient practice the results of assays were expressed in terms of "*betterness*" or "*worseness*" as compared with the standard, which was 22 carats of pure gold with 2 carats of alloy. Carats were divided into quarters (carat grains), eighths of carat grains, and "excess grains," of which it took $7\frac{1}{2}$ to make an eighth of a carat grain. An assay may give a result, for example, like this:

"Worse, 0 carats, $1\frac{5}{8}$ carat grains and 1 excess grain." Mr. Roberts, the chemist of the mint, in explaining the change of practice, remarked:

"Worse, 0, $1\frac{5}{8}$ + 1, as the assay report of an ingot, is at least obscure, while the equivalent statement that the standard of fineness of the ingot is 900 at once suggests that 1,000 parts of the metal contain 900 parts of pure gold."

The metric system continues to be increasingly used for scientific and technical purposes in the nations which have made its use permissive. In the nations which have legally adopted it, its use is becoming more and more general for purposes of commerce and manufacture. No abandonment or diminution of its use is known to your committee.

A bill has been introduced in the House of Representatives at Washington, providing that from and after March 4, 1892, the metric system of weights and measures shall be exclusively employed by the several departments and branches of the Federal Government in the affairs of the United States. This bill has been read twice and referred to the Committee on Coinage, Weights and Measures. A copy of the bill is hereto appended.

In the Ionian Islands the metric system, as used in Greece, has been introduced since their annexation to the kingdom of Greece.

In Hayti, which in 1878 was classed among the countries in which the metric system was neither legalized nor in use, the coinage law passed Sept. 24, 1880, by the Haytian legislative body, was in terms of metric weight and measure exclusively.

In the Dutch East Indies, Dutch West Indies and Dutch Guiana, your committee is informed that the metric system is in use to a limited extent.

In Japan, the linear measures, already mostly decimal, have been modified and made commensurable with the meter.

In Costa Rica, by Congressional decree, the metric system was to come into operation on August 10, 1885.

Scales of Plans and Maps.

One of the earliest applications of the decimal system in this country, was the adoption of the decimal division of the foot by civil engineers. It is used by them in the measurements of distances and heights, and in various computations. It has always been recognized by them as a great labor-saving instrumentality.

The rarity of the use of the decimal system in our old weights and measures, however, occasioned the anomaly that measurements and computations which had been sedulously made in feet and decimals, were almost without exception plotted in terms of inches.

The more general use of decimal methods has rendered the use of scales based on the inch, an impediment to the ready comparison and intelligent examination of plans made from measurements in different systems. Thus, a plan in metric dimensions and drawn to a decimal scale, as is usual, cannot be measured in feet by the ordinary scales based on the inch. Conversely, a plan in British units and drawn to a scale relative to the inch, as is usual, cannot be measured in meters by the decimal scales based on the meter. There must be a numerical computation in each case, or a temporary scale must be constructed to effect the conversion.

This impediment can be avoided by the use of a standard series of decimal scales—that is, scales based upon a decimal subdivision of the unit of measurement—the same series of ratios being used for each different system of measures. For example: if, to a plan drawn from *metric* measurements at a scale of $\frac{1}{1000}$ of nature, we apply a scale of equal parts marked in thousandths of a *foot*, each divis-

ion of the scale will indicate, on the plan, *one foot* of actual size. This and a scale of millimeters would evidently be interchangeable; each giving scale measurements of the plan in terms of its own unit of measure. A plan to be drawn from mixed notes, part the result of metric data and part derived from measurements in feet, would require no numerical conversion of dimensions; those in meters would be plotted by the scale of millimeters, and those in feet by the scale of thousandths of the foot, to the *same scale* and as parts of the *same drawing*.

One of the first difficulties met by an engineer wishing to use the metric system in this country or in England, arises from this incongruity in the relations of plans to nature, decimal and duodecimal. Old measurements and data cannot be used with metric without troublesome processes of conversion.

The adoption and use of a series of scales based upon decimal divisions of the *foot*, which shall be the counterpart of the usual scales based upon the decimal divisions of the *meter*, is much to be desired. Scales based upon the foot instead of the inch are already in use to a limited extent in this country, but they differ in some respects from the scales usually used based upon the meter.

In these scales, the hundredth of the foot, like the hundredth of the meter, should be the primitive unit. This unit being successively multiplied by 1.5, 2, 2.5, 3, 4, 5, 6 and 8, produces the units of the various scales, viz., 0.01 ft., 0.015 ft., 0.02 ft., 0.025 ft., 0.03 ft., 0.04 ft., 0.05 ft., 0.06 ft., 0.08 ft.* Each

DECIMAL SCALES.

Scales.		Ratio in Decimal Measures.			Ratio in Duodecimal Measures.
$\frac{1}{1}$	........1.00	1.00	unit* to	1 unit†	Full size.
$\frac{1}{2}$	........0.50	0.50	" "	1 "	6 inches to 1 foot.
$\frac{1}{4}$	........0.25	0.25	" "	1 "	3 " " 1 "
$\frac{1}{5}$	........0.20	0.20	" "	1 "	2.4 " " 1 "
$\frac{1}{6.7}$	........0.15	0.15	" "	1 "	1.8 " " 1 "
$\frac{1}{10}$	........0.10	0.10	" "	1 "	1.2 " " 1 "
$\frac{1}{12.5}$	........0.08	0.08	" "	1 "	1.04 feet to an inch.
$\frac{1}{16.7}$	........0.06	0.06	" "	1 "	1.39 "
$\frac{1}{20}$	........0.05	0.05	" "	1 "	1.67 "
$\frac{1}{25}$	........0.04	0.04	" "	1 "	2.08 "
$\frac{1}{33.3}$	........0.03	0.03	" "	1 "	2.78 "
$\frac{1}{40}$	........0.025	0.025	" "	1 "	3.33 "
$\frac{1}{50}$	........0.02	0.02	" "	1 "	4.17 "
$\frac{1}{66.7}$	........0.015	0.015	" "	1 "	5.56 "
$\frac{1}{100}$	........0.01	0.01	" "	1 "	8.33 "
$\frac{1}{125}$	........0.008	0.08	" "	10 unit†	10.42 "
$\frac{1}{166.7}$	........0.006	0.06	" "	10 "	13.89 "
$\frac{1}{200}$	........0.005	0.05	" "	10 "	16.67 "
$\frac{1}{250}$	........0.004	0.04	" "	10 "	20.83 "
$\frac{1}{333.3}$	........0.003	0.03	" "	10 "	27.78 "
$\frac{1}{400}$	........0.0025	0.025	" "	10 "	33.33 "
$\frac{1}{500}$	........0.002	0.02	" "	10 "	41.67 "
$\frac{1}{666.7}$	........0.0015	0.015	" "	10 "	55.56 "
$\frac{1}{1000}$	........0.001	0.01	" "	10 "	83.33 "
$\frac{1}{1250}$	........0.0008	0.08	" "	100 "	104.16 "
$\frac{1}{1666.7}$	........0.0006	0.06	" "	100 "	138.89 "
$\frac{1}{2000}$	........0.0005	0.05	" "	100 "	166.67 "
$\frac{1}{2500}$	........0.0004	0.04	" "	100 "	208.33 "
$\frac{1}{3333.3}$	........0.0003	0.03	" "	100 "	277.78 "
$\frac{1}{4000}$	........0.00025	0.025	" "	100 "	333.33 "
$\frac{1}{5000}$	........0.0002	0.02	" "	100 "	416.67 "
$\frac{1}{6666.7}$	........0.00015	0.015	" "	100 "	555.56 "
$\frac{1}{10000}$	........0.0001	0.01	" "	100 "	833.33 "
$\frac{1}{12500}$	........0.00008	0.08	" "	1000 "	1041.67 "
Etc.	Etc.		Etc.		Etc.

* A triangular boxwood scale of this description, designed by the Chairman of the Committee, and made by Darling, Brown & Sharpe, of Providence, R. I., was exhibited at the meeting of the Society.

† The unit may be the meter, or the foot divided decimally.

of these units may be used to represent 0.1 ft., 1 ft., 10 ft., 100 ft., 1,000 ft., etc., of nature, giving rise to the ratios shown in the following table. The ratios in the central column are not expressed in terms of the units of any system, but abstractly, as these ratios will apply to any system in which the unit of linear measure is subdivided decimally.

This series of scales possesses the intrinsic merit of being more uniformly distributed than are the scales usually employed. Thus between the scales 0.008 and 0.004, corresponding to 10.42 and 20.83 feet to an inch respectively, are two scales, 0.006 and 0.005, which supply a long-felt want. The old scales of 50 and 60 feet to an inch are replaced by the decimal scale 0.0015, or 55.56 feet to an inch. The useful scales 10, 20, 40, 80 and 100 feet to an inch, are almost exactly represented in the decimal series. The scales 0.0001, 0.0002, 0.0003, 0.0004, 0.0008 and some of their decimal derivatives are now in use in the U. S. Coast and Geodetical Survey.

The following is a concise method of expressing one of these scales upon a plan :

Scale, { 0.002 meter to a meter, / 0.002 foot to a foot, } or $\frac{1}{500}$.

It will be noticed that a peculiarity of these scales is that each can be expressed *exactly* as a decimal fraction. One consequence of this peculiarity is that scale measurements may be conveniently made upon a plan drawn to one of these scales, by means of the ordinary pocket rules belonging to any decimal system, as a meter rule, or a foot rule divided decimally.

In conclusion, your Committee recommends :

1. That in view of the continued use and spread of the metric system, it be adopted for all purposes where its use presents substantial advantages.

2. That upon every plan that has its scale shown by a graduated line indicating other than metric measures, a second line be graduated indicating metric units.

3. That, so far as is practicable, every plan or map, whether made from metric measurements or otherwise, be drawn to such a scale that its linear relation to nature can be expressed exactly by a decimal fraction ; preference being given to the scales 0.01, 0.015, 0.02, 0.025, 0.03, 0.04, 0.05, 0.06, 0.08, and their decimal derivatives.

Respectfully submitted for the Committee,

CHARLES H. SWAN, Chairman.

BOSTON, March 2, 1886.

49TH CONGRESS, 1ST SESSION.

H. R. 2119

IN THE HOUSE OF REPRESENTATIVES.

JANUARY 6, 1886.

Read twice, referred to the Committee on Coinage, Weights and Measures, and ordered to be printed.

Mr. EVERHART introduced the following bill :

A BILL

To establish the metric system of weights and measures in the Departments of the Government.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the fourth day of March, anno Domini eighteen hundred and ninety-two, the metric system of weights and measures, as recognized and expressed in section thirty-five hundred and seventy of the Revised Statutes, shall be exclusively employed by the several Departments and branches of the Federal Government in the affairs of the United States: *Provided*, That in all other transactions than those in which the United States is a party it shall be lawful to employ the weights and measures now in use.

SEC. 2. That a knowledge of the said metric weights and measures shall be taught in all the schools and colleges now under the control of the Federal Government, or hereafter aided by it, or such knowledge shall be required for admission to the said schools and colleges.

SEC. 3. That all laws inconsistent herewith are hereby repealed.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

To the Boston Society of Civil Engineers:

GENTLEMEN: The Government has the honor to submit the following in regard to the Boston Society of Civil Engineers, for the year ending March 19, 1886:

One of our most valued Members, Mr. Henry M. Wightman, died upon the 3d of April, 1885. An appropriate notice of the life and work of this engineer has been presented to the Society and placed on record.

The Society has during the past year lost by resignation Maj. C. W. Raymond, of the U. S. Corps of Engineers, who has been transferred by his Department to another sphere of labor, leaving important work in this vicinity to be completed by others. In him our Society has lost a useful Member and the community a most efficient servant.

Two names have been dropped from our list for non-payment of dues, and thirty new names have been added, making the total number of Members at the present time one hundred and fifty-two, including six honorary and two corresponding Members. This number entitles the Society to another representative on the Board of Managers of the Association of Engineering Societies.

Regular meetings have been held on the third Wednesday of each month, excepting July and August, and in addition to the above there have been three special meetings. The average attendance at the meetings has been thirty-two. Three addresses have been delivered and fifteen papers have been presented to the Society, the latter having been followed by a great deal of valuable discussion.

Excursions have been made during the year to the Pacific Mills and the water-works at Lawrence, to Boston Harbor, to the works of the Boston Gas Light Company, to the Watertown Arsenal, and to the Massachusetts Institute of Technology.

The Society has also had the pleasure and the profit of attending the meeting of the Society of Mechanical Engineers held in Boston in November last.

One of the most important steps taken during the past year has been the removal of the Society's headquarters to the very pleasant and convenient room in the Boston & Albany Railroad station. This change has enabled the Society to place its valuable collection of books and periodicals in a condition to be used. The Society has also arranged for an exchange of publications with the Institution of Civil Engineers, Great Britain, and twenty-three volumes of the Minutes of the Proceedings of that institution have been received.

During the year the By-Laws have been amended in regard to the order of business at the meetings, by which it is believed that a more satisfactory disposition of the time will be made.

In conclusion, the Government has a great deal of pleasure in congratulating the Society upon the present very satisfactory condition of its affairs. The Society is growing steadily, both in numbers and in usefulness. Let us keep it in such a state that every Member shall feel that it is good for him to belong to it.

Respectfully submitted,

GEORGE L. VOSE, President.
L. FRED'K RICE, Vice-President.
HORACE L. EATON, Secretary.
HENRY MANLEY, Treasurer.
ALBERT F. NOYES, Librarian.

ABSTRACT OF TREASURER'S REPORT FOR THE FINANCIAL YEAR 1885–86.

Balance on hand March 14, 1885		$275.69
Assessment for current year, 95 members at $6	$570.00	
Non-resident dues current year, 5 members at $3	15.00	
Non-resident dues coming year, 15 members at $3	45.00	
Assessment levied March 15, 1876	5.00	
Periodicals sold	5.88	
		640.88
Interest on current balance		13.17
		$929.74

Receipts—Permanent Fund.

Cash on hand as per last report	$257.53
Entrance fees	296.00
Interest on bonds	86.00
	$639.53

Disbursements.

Association of Engineering Societies	$404.23
Rent	45.00
Secretary, salary	50.00
Binding periodicals	11.00
Printing, postage and stationery	137.53
Periodicals	32.65
Annual dinner	23.00
Janitor	5.00
Excursion to Lawrence	27.00
Book cases and moving books	30.75
Pamphlets presented to American Society of Mechanical Engineers	74.06
Cash on deposit	89.50
	$929.74

Funds of the Society in the Hands of the Treasurer March 10, 1886.

One Republican Valley Railroad 6 per cent. bond	$600.00
One Atchison, Topeka & Santa Fe "plain 5"	1,000.00
Permanent fund, cash	559.19
Current fund, cash	89.50
	$2,248.69

HENRY MANLEY, Treasurer.

MARCH 24, 1886:—A special meeting of the Boston Society of Civil Engineers was held this evening, Mr. J. W. Marden, President of the New England Railway Club, in the chair, twenty members of this Society present.

This was a joint meeting with the New England Railway Club, and was held to continue the discussion of the relation of the road-bed to the rolling stock.

Mr. F. D. Adams, of the N. E. Railway Club, read a letter from Mr. H. S. Goodwin, of the Lehigh Valley R. R., written in answer to a circular sent by the N. E. Railway Club. This letter referred to the practice on the Lehigh Valley R. R. observed in the gauge of tracks, spacing of frog throats and guard rails. The form of rail head in use, the maintenance of gauge and alignment, the allowance in width of gauge on curves, the result of wear on the surface of rail, effect of sand, trouble from frogs and switches on sharp curves, weight of rail and strength of bridges, were also given.

Mr. M. N. Forney referred to the designing of rail head and rail, the form of tread and flange of wheel, the diversity of rail sections, which causes great confusion among manufacturers, and the necessity of a uniform standard of gauge

of track, and tread and flange of wheel. Coning of wheels was referred to as a superstition, and the straight tread was stated to be the better because of its more uniform and larger bearing surface on the rail. The proper curvature of the wheel at the throat of the flange was stated to be a great point in dispute, and a uniform radius of wheel and rail was advocated. The discrepancies between the gauge of track and wheels was noticed, and the speaker contended that this difference was undoubtedly the cause of many accidents.

Mr. Greggs, of the Prov. & Worcester R. R., did not agree with Mr. Forney regarding a uniform radius of wheel and rail, and gave the form adopted on that road. Special attention should be given to the centring of wheels previous to boring, and the bore should be square with the back of flange. Wheels on the same axle should be made of metal of equal density to avoid unequal wear.

Mr. Lauder, of the O. C. R. R., fully agreed with Mr. Forney on the necessity of accurate fitting of throat and corner of rail, and also on the form of flange of wheel, except the chamfer on the outer edge, which, he stated, wore out the point of the White switch used on the O. C. R. R.

Mr. L. B. Bidwell, of the N. Y. & N. E. R. R., claimed that a coincidence of throat of wheel on flange did not save wear because of its distance from the rolling surface of the wheel, and that there would be a continual rubbing taking place whenever the flange struck.

Mr. George Richards, of the B. & P. R. R., approved Mr. Forney's wheel.

Mr. Adams approved Mr. Forney's design, and urged the necessity of an agreement between the representative of the rolling stock and permanent way as a necessity, and claimed that the limit gauge is not a point at issue.

Mr. Marden advocated the adoption of a limit gauge and the use of the Master Car-Builders' standard. He disagreed with Mr. Adams on the propriety of discussing the limit gauge at this meeting, stated that there is a diversity of opinion on the proper distance between guard rail and track and that it is impracticable to decide on a limit gauge of wheels until a standard distance between guard rail and track is agreed upon. The different practice on different roads on this point was referred to.

Mr. Adams conceded what Mr. Marden claimed, gave the limit gauge of wheels on the B. & A. R. R., and claimed that wheels of 4–5⅜ in. gauge could be safely run on all roads.

Mr. M. W. Oliver claimed that before you make a standard gauge the form of rail must be agreed upon, that the throat of wheel should coincide with corner of rail, that the variation in size of wheels causes as much friction as does curve in track, that difference in diameter of wheels may cause sharp flanges, and that slightly crowned rail and slight coning of wheel give the most favorable construction.

H. L. Eaton, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

April 7, 1886:—Club was called to order at 8:30 p. m., at Mercantile Library, by President McMath, eighteen members being present. The minutes of last meeting were read and approved. The executive committee reported, recommending that Messrs. Wm. T. Angell and Wm. D. McQuestin be elected Members. They were balloted for and elected. Mr. Jno. A. Sobolewski was proposed for membership by Messrs. R. E. McMath and T. D. Miller.

Mr. Robert Moore, the delegate from this Club to the meeting of the Civil Engineers' Committee on National Public Works, held at Cleveland, March 31 and April 1 and 2, reported: A permanent organization was effected. Its name to be The Council of Engineering Societies on National Public Works. The expense of carrying on the work of the Council to be met by a request on each society represented. The permanent officers are: President, L. E. Cooley; Vice-President,

Prof. J. B. Davis; Secretary and Treasurer, Prof. John Eisenmann. Executive Board: L. E. Cooley, J. B. Davis, John Eisenmann, August Kurth, L. M. Haupt, R. E. McMath and L. J. Barbot.

The following committees were appointed to gather information in regard to the conduct of public work in various countries: Mr. Barbot, France and Italy; Mr. Haupt, United States; Mr. Kurth, Austria and Hungary; Mr. McMath, Great Britain and Canada.

Mr. Robert Moore read a paper on "Tables for Determining the Sizes of Sewers, by Kutter's Formula." The paper was discussed, followed by a general discussion.

[*Adjourned*] THOS. D. MILLER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

APRIL 6, 1886:—The 223d meeting was held at 7:30 P. M., President Wright in the chair.

The minutes of the two preceding meetings were read and approved.

Applications to be admitted to membership were received from:

John B. Allan, Manager for E. P. Allis & Co., Chicago.

Samuel R. Ballard, Civil Engineer, Burlington, Iowa.

Samuel A. Bullard, Architect and Engineer, Springfield, Ill.

Joseph Phelps Card, Wood Preserving, Chicago.

John Charles DesGranges, Construction Engineer Water-Works, Aurora, Ill.

Eric Gustaf Ericson, Assistant Engineer Pennsylvania Co., Wooster, Ohio.

John E. Ericson, Civil Engineer, Chicago.

William A. Hammett, Manager and Mechanical Engineer for New York Steam Power Co., Chicago.

Abner C. Harding, Real Estate and Insurance, Chicago.

Gustave Bernard Hegardt, Civil Engineer, Beardstown, Ill.

Eyvind Lee Heidenreich, Construction of Grain Elevators, Chicago.

Marvin Hughitt, Second Vice-President and General Manager Chicago & Northwestern Railway Company, Chicago.

John Lundie, Assistant Engineer, City Hall, Chicago.

Augustus F. Nagle, General Western Agent for Providence Steam & Gas Pipe Co., Chicago.

John Nelson Ostrone, Assistant Engineer Bridge Department, Chicago, Burlington & Quincy Railroad, LaGrange, Ill.

Theodore Parker, Assistant Engineer Chicago, Burlington & Quincy Railroad, Burlington, Ia.

Orrin W. Potter, President North Chicago Rolling Mill Co., Chicago.

Ethan Philbrick, Assistant Engineer Chicago & Alton Railroad, Western Springs, Ill.

Henry Raeder, Architect and Engineer, Chicago.

Albert W. Sullivan, Division Superintendent Illinois Central Railroad, Cairo, Ill.

William Bryant Throop, Roadmaster Chicago Division, Chicago, Burlington & Quincy Railroad, Aurora, Ill.

Messrs. Frank Lawlor and Ferd Hall were transferred to the grade of Members.

Messrs. Horace C. Alexander and Orlando H. Cheney were elected Members.

Mr. Cooley, for Committee on National Public Works, reported progress, and Mr. Wright, for same Committee, reported receipt of subscriptions amounting to $47.49.

Mr. Gottlieb, for Committee on American Society of Mechanical Engineers, recommended that a committee of six be appointed as a Reception Committee and

that the Society offer its hall for the use of the Convention May 25, 26, 27, and 28.

It was voted that the recommendations of the Committee be adopted, and that the present Committee should add three members to its number and be the Reception Committee.

The Secretary read a Memoir of Edward B. Talcott, by Mr. Willard S. Pope.

The President announced Standing Committees as follows:

COMMITTEES.

1. Surveys and Topography, Chas. MacRitchie, Z. A. Enos.
2. Materials, O. Chanute, A. W. Cooke.
3. Construction, Allan D. Conover, J. T. Dodge.
4. Bridges, Maurice Seifert, George R. Bramhall.
5. Transportation, Railroads, Canals, etc., C. H. Hudson, H. C. Alexander.
6. River and Harbor Improvements, H. B. Herr, G. A. M. Liljencrantz.
7. Water Supply, Sewerage, etc., Samuel McElroy, J. A. Cole.
8. Fuel, Heat for Industrial Purposes, John Zellweger, W. S. Bates.
9. Lighting, Heating and Ventilating Buildings, J. M. Howells, R. F. Hartford.
10. Mining, C. E. Bilin, Irving A. Stearns.
11. Tools and Machinery, W. H. Lotz, J. Saltar, Jr.
12. Jurisprudence of Surveys, C. W. Irish, A. V. Powell.
13. Weights and Measures, Chas. Latimer, L. E. Cooley.
14. City Engineering, Samuel G. Artingstall, W. F. Goodhue.
15. National Public Works, L. E. Cooley, H. B. Herr, A. W. Wright.

A paper on "Long Span Bridges," by Mr. J. F. Clarke, was read by Mr. Hall. A criticism was read by Mr. Gottlieb. The two papers were referred to Committee on Bridges.

A paper on "A Time-Table for Lighting Street Lamps," by Mr. J. M. Howells, was read by Mr. Cooley.

The amendments to the By-Laws proposed at the meeting March 2 were adopted.

[*Adjourned*.] L. P. MOREHOUSE, Secretary.

At the May meeting a paper will be read by Mr. Chanute, "The Preservation of Timber." Advance sheets will be sent to members willing to discuss this paper.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. June, 1886. No. 8.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

THE EFFICIENCY OF A PIPE SYSTEM FOR FURNISHING WATER TO FIRE-ENGINES.

By S. Bent Russell, Member of the Engineers' Club of St. Louis.

[Read February 17, 1886.]

The problem before us is how to furnish at any point in a city a sufficient quantity of water to supply a maximum number of fire engines and use the least quantity (tonnage) of pipes, consistent with assured safety.

In practice, the problem is combined with that of water distribution for domestic purposes.

In the study of this subject, the great need is for some method of testing our system of pipes which will show if it can furnish on demand the required quantity of water. The usual method of gauging the efficiency of a system of pipes for furnishing water to fire-engines is to wait for a conflagration. If there is sufficient water to extinguish the fire, the efficiency of the system at that point may be called good. This is, however, a very expensive test, especially as each point in our city must be tested for itself.

The chief object of this paper is to show a very inexpensive and fairly reliable method of testing the efficiency of a system of pipes for this purpose, which the writer has found of great value in studying the water-pipe system of St. Louis.

The fire-plug used in the experiments is of the underground variety, the nozzle being set a few inches below the level of the sidewalk. This pattern, with slight variations in detail, is the one most used in St. Louis. The nozzle or orifice is three inches inside diameter, and points at an angle of about sixty degrees with the horizontal plane.

To consider the jet thrown from such an orifice, let E equal the vertical height in feet to which water is thrown above orifice.

Let A equal the horizontal distance in feet to which water is thrown from the orifice.

Let V equal the velocity of discharge in feet per second.

Let i equal the angle which the axis of jet at the orifice makes with the horizontal plane.

Then, from the laws of projectiles [compare Bennett's D'Aubisson page 255],

$$E = v^2 \frac{sin^2\, i}{2\, g} \text{ and } A = \frac{2\, v^2\, sin.\, i\; cos.\, i}{g}$$

These two expressions may be combined in the form [see Note 1] :

$$v^2 = 2\, g\, E\, (1 + R^2), \text{ or}$$

$$v = \sqrt{2\, g\, E\, (1 + R^2)}, \text{ when } R = \frac{A}{4\, E}$$

Remark : $\frac{A}{4\, E}$ is also equal to the cotangent of i, or is equal to the tangent of the angle made by the jet at the orifice with the vertical. [See Bennett's D'Aubisson].

Table I. gives the results of twelve experiments at the Old Benton Street Reservoir, made by Mr. Edw. Flad and the writer, Dec. 4, 1884.

These experiments were made with one fire-plug controlled by a six-inch stop valve, which was used to regulate the discharge. The discharge was measured by one of Colonel Flad's velocimeters, which had been tested in place by means of a measured tank, and found to give the correct discharge with an error rarely over two or three per cent. The height and length of the jet were measured by triangulating.

Table I. also compares the discharge as given by the velocimeter with the discharge calculated from the height and length of the jet by the formula

$$v = \sqrt{2\, g\, E\, (1 + R^2)}$$

Taking for R the average of the twelve experiments, as shown in the table, but one experiment out of twelve gave a difference of over four and one-half per cent. The total of the discharges given by the formula differs but one per cent. from the total by measurement.

Table II. shows the results of six experiments with five different fire plugs made by Mr. Wm. Penney and the writer at the Fair grounds, December 16, 1885. These fire-plugs get their supply through a six-inch Crown meter which was used to measure the discharge. The height and length of jets were measured with a ten-foot transit rod.

Table II. also compares the discharges calculated by the formula with those given by meter.

The maximum difference for one experiment is seven and one half per cent.

The value of the ratio $\frac{A}{E}$ varies in practice from 1 to 3, but is in the majority of cases between 1.5 and 2.0.

Table VIII. gives values of $\sqrt{1 + R^2}$ for different values of $\frac{A}{E}$ for convenience in using the formula.

Table III. gives the discharge in gallons per minute from a three-inch fire-plug nozzle for different heights of jet, where $\frac{A}{E} = 1.60$, calculated by the formula. The discharges for any value of $\frac{A}{E}$ may be found by adding the percentage correction given in column 5, Table VIII.

Within the range of the above experiments, the formula seems to be

correct enough for practical use. The highest jet experimented on was twenty-nine feet. Fire-plugs in St. Louis will in some places throw a jet over sixty feet high, but, as will be seen further on, the lower jets are those usually studied.

Tables IV., V. and VI. give the results of seventeen experiments to determine the coefficient of discharge for a fire-plug, or, in other words, to determine the pressure in the main necessary to discharge a given quantity of water from the fire-plug. In each experiment the pressure in the main was taken with an open-top mercury gauge.

In the experiment of Table VI., the discharge was measured by meter. In each of the other experiments the discharge was calculated by the formula from the height and length of jet.

The values of the coefficient of discharge vary from 0.53 to 0.95 in the experiments: 0.77 seems a fair average value for the coefficient of discharge, or, in other words, the actual discharge from a fire-plug may be taken to be 77 per cent. of the theoretical discharge from a three-inch orifice due the pressure in the main while the fire-plug is open. This coefficient is the one used throughout these experiments. The pressures referred to are all reduced to the level of the fire-plug nozzle.

Table VII. gives the head in feet in the main necessary to discharge different quantities of water from a fire-plug, calculated with a coefficient of discharge of 0.77.

From Table VII., knowing the quantity of water discharged by a fire-plug when full open, we may find the head in the main while the fire-plug is running.

Let H equal the pressure or head in feet at the fire-plug before opening.

Let h_r equal equal the head in the main while the fire-plug is open.

Then $H - h_r$ is equal to the loss of head due to resistance in the pipes.

If a fire-plug connected with a pipe or system of pipes is opened full, the quantity of water discharged will depend on: 1st. The head in the main before opening the fire-plug, or the difference of level between the fire-plug and the surface of the water in the reservoir or stand-pipe which regulates the pressure in said pipe or system of pipes. 2d. The resistance to flow in the pipe, or system of pipes, which resistance depends on the quantity of water discharged and the condition and size of pipes.

Reversing the above law, if we have the quantity of water which a fire-plug will discharge, and the static head at the fire-plug before opening, we may determine the resistance to flow of the pipe or system of pipes supplying the fire-plug.

In practice, to study the efficiency of a system of pipes, we make the following experiment at each fire-plug: 1. A spring gauge is screwed on the nozzle of the fire-plug, the valve opened and the pressure recorded. 2. The fire-plug valve is opened full and the height and length of the jet measured with a transit rod and recorded. Thus the only instruments needed are a spring gauge set in a brass cap fitting the fire-plug nozzle and a transit rod divided in feet. Any intelligent mechanic can be trusted to make the experiment for ordinary purposes.

From the data thus found we may determine for each experiment:

1. By Tables III. and VIII., or by the formula, the quantity of water discharged per minute in the experiment.

2. From the discharge, by Table VII., the head in the main during said discharge.

3. The difference of head in the main when the fire-plug is open from the head before opening, or the loss of head due to friction for the quantity of experiment.

Let h equal this difference or loss of head due friction, etc. We find a different value of h and a different discharge (q) for each fire-plug in the district experimented on.

The following formula, a modification of M. Darcy's, is published by Mr. Kirkwood. [See "Brooklyn Water-Works," p. 54.]

$$h = \frac{v^2 l}{c d}$$

h = loss of head in feet.

v = velocity in feet per second.

l = length of pipe in feet.

d = diameter of pipe in feet.

c = a constant varying with condition of pipe.

If this be true of a single pipe, it must be true of a system of pipes (see Note 2), delivering water at one point.

If l and d be constant, let $v^2 = m q^2$ and q equal the discharge in gallons per minute, and let

$$\frac{m l}{c d} = K, \text{ then } h = K q^2, \text{ or}$$

$$\frac{h_1}{h} = \frac{q_1^2}{q^2}$$

Let h equal the loss of head of experiment.

Let h_1 equal the loss of head for a quantity, q_1.

Let q equal the discharge of experiment.

Let q_1 equal an assumed discharge.

Having h and q from our experiments for each fire plug, and assuming q_1 the same for each, we may find the h_1 for each thus:

$$h_1 = h \frac{q_1^2}{q^2}$$

and thus the comparative losses of head for a given quantity of water.

This gives a method of comparing our experiments. Taking $q_1 = 300$ gallons per minute h_1 will have values ranging from 0 to 150 feet at fire-plugs in the St. Louis distribution.

Let H equal the pressure at the fire-plug when not running. Then H is the available head at the fire-plug. In our experiment only the part h was used in overcoming friction. The remaining head was needed to discharge the water through a three-inch nozzle.

Let us assume the orifice so large that but five feet head is necessary for discharge, then we shall have $H - 5 = h_2$ head to overcome friction. Five feet was chosen because five feet head will discharge about three hundred gallons per minute from a fire-plug [see Table VII.], which is a fair supply for a fire engine [see Ellis' Tables].

Turning to the equation, page 2,

$$\frac{q_2^2}{q^2} = \frac{h_2}{h}$$

we get

$$q_2 = q \sqrt{\frac{h_2}{h}}$$

or if we have a head h_2 to overcome friction, the discharge will be q_2.

For convenience call the expression

$$q_2 = q \sqrt{\frac{h_2}{h}} = q \sqrt{\frac{H - 5}{h}}$$

the "comparative efficiency" of the distribution at that point, as it expresses as nearly as may be determined in this way the quantity of water which the distribution system will furnish at that point.

This gives a second method of comparing our experiments. If two fire-plugs give the same values of h_1 their "comparative efficiency" will depend upon their respective "available head."

Plates I. and II. show diagrams of two sections of the water distribution system of St. Louis. The straight lines show the water pipes. There are three sets of curved lines. The first set is of contour lines. The second set is made up of lines showing different values of the expression

$$h_1 = h \frac{q_1^2}{q^2}$$

when q_1 equals 500 gallons per minute, or different losses of head for a discharge of 500 gallons per minute. Any two points on one of these lines have the same loss of head for that discharge. For example, in Plate I. the first of these lines passes through points having a loss of head of five feet for 500 gallons per minute. The second of these lines passes through points having a loss of head of ten feet for 500 gallons per minute discharge at that point, etc.

The third set is made up of lines showing different values of the expression

$$q_2 = q \sqrt{\frac{H - 5}{h}}$$

or different "comparative efficiency." Any two points on one of these lines have equal "comparative efficiency." For example, in Plate I. the first of these lines passes through points having a "comparative efficiency" of 2,000, the second passes through points having a comparative efficiency of 1,500, etc.

These diagrams show the way in which distribution may be studied by this method.

If the ground were level, the second and third sets of lines would be parallel, so to speak. If the loss of head for 500 gallons per minute discharge were equal at every point, the third set of lines would be parallel to the contour lines.

Table X. gives the "comparative efficiency" of some of the points of the district shown on Plate II., before and after laying the twenty-inch pipe on Shenandoah street.

Table IX. shows the "comparative efficiency" of two points on Chestnut street under different conditions of distribution.

In the preceding method we have assumed the formula $h = K q^2$, given by Kirkwood, for any one pipe to be correct, and that K is constant for any discharge. Most hydraulic engineers, however, say that

the co-efficient K is not constant, except at high velocities. This assumption was used because it was the only one by which the experiments could be compared or reduced to a comparable shape. In calculating "comparative efficiency," the error from making the above assumption is on the side of safety. The results found with this assumption and by this method of experiment will probably be much nearer the truth than those calculated by the most precise formula, with no data but the size, length and age of the pipes. By a careful inspection of the conditions of the experiments the probable error by this method may be estimated and allowed for.

Tables XI., XII., XIII. and XIV. give tests of the equation $h = K q^2$ when K is constant.

Tables XII. and XIII. were made from experiments on a *single* line of six-inch pipe. In these experiments as shown, the formula was found practically correct.

Tables XI. and XIV. were made from experiments on fire-plugs supplied by a *system* of pipes. In each of these two experiments two fire-plugs about 300 feet apart on a twelve-inch pipe line were chosen, the twelve-inch line being supplied by a system of six-inch or six and eight-inch pipes. These two fire-plugs were considered to be at one point as the loss of head for that discharge in 300 feet of 12-inch pipe would be comparatively inconsiderable.

As seen in Table XI., the two fire-plugs running together gave on Sarah street from fifteen to twenty per cent. more discharge than calculated by the formula from the fire-plugs run separately for the same loss of head. On Farrar street, however (see Table XIV.) the discharge given by two fire-plugs was only from two to ten per cent. greater than that due the loss of head by the formula.

From these results it would seem safe to say that when the ratio of velocities is not great, and when the velocities are not too small, the formula $H = K q^2$ may be used, where only approximate results are desired.

This method of studying a system of pipes is, of course, far from having scientific accuracy, but will be found of much use as a simple and handy way of gauging water supply.

The same principle has been used, of later years, in tests of water-pipe systems; for example, the requirement that six fire-streams 100 feet high should be thrown simultaneously from one-inch nozzles as a test of the water supply. The method herein given is much simpler in practice, and probably more reliable. It does not, certainly, show directly how many *engines* may be used around any assumed point, but is a decided step toward the solution of that question. We are enabled to compare different districts of the city and different points in a district. Knowing the arrangement of pipes and fire-plugs in any special case, after finding the "comparative efficiency" of each point, the efficiency of a number of points discharging at the same time could probably be approximated. A large factor of safety should be used, however, to allow for probable error.

Tables of loss of head due to friction in water pipes must not be too much relied on in this work, even in the simplest case of a single line of pipe. Experiments in this city show that no two lines of pipe of the

same diameter and length will have the same loss of head for the same quantity discharged. The co-efficients vary as much as 100 per cent. In some lines of six-inch pipe the loss of head per 1,000 feet for a given quantity of water is more than twice that given by ordinary tables or formulas. And yet pipes do not seem to corrode much in this city as compared with some others.

This want of uniformity may be largely attributed to branches, valves, etc., not allowed for in the computation, and to the manner in which the pipes are laid as well as to the age of pipe.

The requirements of a system of distribution for domestic purposes differ from those of a system for fire protection in that the former requires a capacity to furnish a small quantity of water to every point of the system at the same time, while the latter requires a capacity to furnish a large quantity of water at any one point of the system.

A system of pipes designed for domestic purposes only would have, under ordinary conditions, a capacity unnecessarily large for fire protection near the point of supply, while at the points farthest from the supply the capacity would be insufficient for fire protection. This may be expressed otherwise by saying that the most economical system of pipes for domestic service would probably be similar to the veins of a leaf, *i. e.*, radiating out from the source of supply and decreasing in size as the distance increased.

The most economical system for fire service, on the other hand, would probably be more similar to the meshes of a net.

Systems of pipe for fire service may be divided into two classes:

1st. Where portable fire-engines are used to throw the fire-stream, taking the water from the mains.

2d. Where the direct pressure in the main is used to throw the fire-stream.

The first class is in use in all the older cities. The problem of supply is the same in both classes, the only difference being in the amount of head at which the desired supply must be furnished. The additional head necessary for direct service is equal to the friction loss of head in the fire-hose, plus the head required at the hose nozzle to throw the stream desired. As St. Louis uses a system of the first class, the safe requirement here is that the desired supply be delivered into the valve chamber of the fire-engine without suction.

The quantity of water needed to supply the fire-engines at a fire is a very uncertain one.

There are twenty-five engine companies in St. Louis. We may safely assume twenty fire-engines throwing 300 gallons per minute apiece, to take a maximum quantity. This would be 6,000 gallons per minute, which would be delivered by one 20-inch pipe at a velocity of about 6 feet per second.

This velocity in the 20-inch pipe would give a loss of head of about 50 feet per mile.

The greater the distance between fire-plugs the less water a number of engines will require, as the efficiency of a fire-engine diminishes very rapidly with the length of hose; moreover, the engines are distributed

over a greater number of water pipes and so interfere with each other's supply to a less degree.

The quantity of water demanded in a district depends also on the value of improvements. The same protection that we would furnish in a well-built up first-class business section is not demanded in a sparsely-built residence district. If we provide for a demand of 6,000 gallons per minute as a maximum in the former, 1,000 gallons per minute would seem a fair allowance for the latter, and 2,500 gallons per minute should be ample supply for the best residence district.

In laying out a system of pipes for a city, it should be so designed that the greater part of the loss of head should be in the smaller pipes, that is, that when one or more engines are drawing water the greatest loss of head should be near the engines, and not in the large mains which supply the district.

This rule is necessary for economy, as one large main will supply several districts, and any lack of capacity in it would affect them all.

After long experience it has been considered unsafe in this city to use any pipe of less than six inches diameter to supply fire-plugs.

One more great complication embarrasses the providing of a city with a cheap and efficient system of pipes. This is given by the irregular growth of the city in different directions, and by the way improvements are spread over so much larger an area than need be.

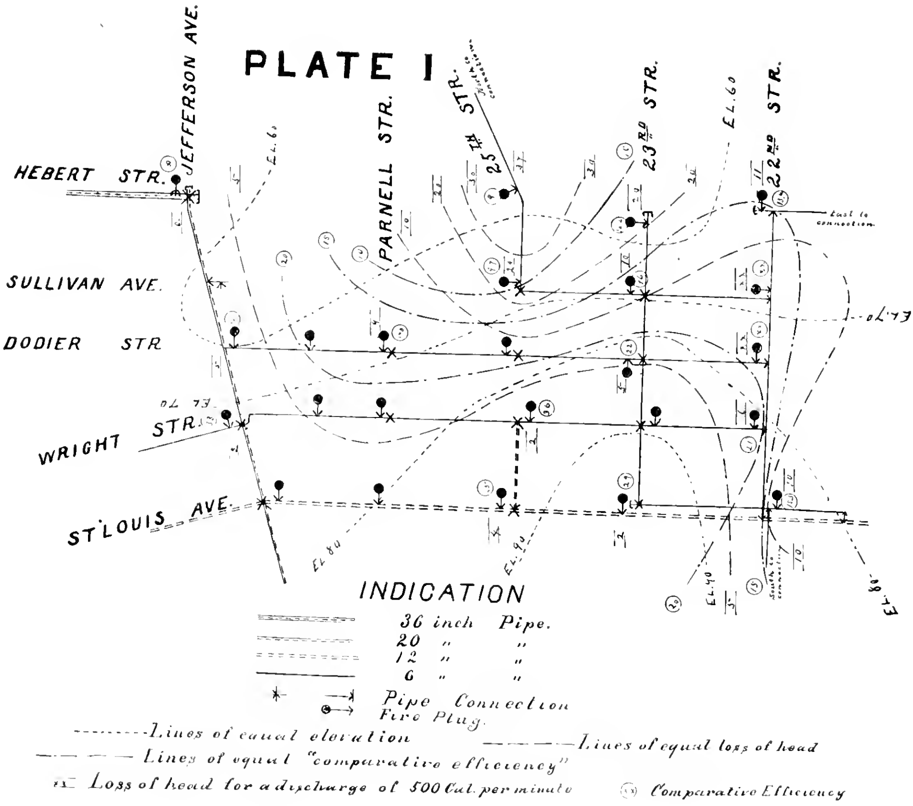
The engineer must make the best use of what has been done in the past, make the best arrangement for present needs and provide as well as may be for the probable contingencies of the future.

TABLE I.

Experiments at Old Benton Street Reservoir, Dec. 4, 1884, with one fire-plug.

No. of experiment.	Height of jet in feet. E	Length of jet in feet. A	$\frac{A}{E}$	$22.032\sqrt{2gE(1+R^2)}$ when $R = \frac{A}{4E} - 0.40$. q	Discharge in gallons per minute, measured by velocimeter. q	Difference in gallons per minute.	Difference per cent.
1.....	10	16	1.60	573	587	— 14	— 2.4
2.....	20	$29\frac{1}{2}$	1.47	849	837	12	1.4
3.....	$27\frac{1}{2}$	$38\frac{1}{2}$	1.40	998	988	10	1.0
4.....	$8\frac{1}{2}$	$13\frac{1}{2}$	1.59	553	535	18	3 4
5.....	1.2	2.2	1.83	207	233	— 26	— 11.1
6.....	2.3	3.9	1.70	284	297	— 13	— 4.3
7.. ..	$4\frac{1}{2}$	7.8	1.73	403	411	— 8	— 1.9
8.....	$8\frac{1}{2}$	$14\frac{1}{2}$	1.71	553	550	3	0.5
9.....	$12\frac{1}{2}$	20	1.60	671	667	4	0 6
10.....	19	$29\frac{1}{2}$	1.55	829	809	20	2.5
11.. ..	25	40	1.60	970	934	36	3.8
12.....	29	$40\frac{1}{2}$	1.40	1027	1006	21	1.6

PLATE I


JEFFERSON AVE.
PARNELL STR.
25TH STR.
23RD STR.
22ND STR.
HEBERT STR.
SULLIVAN AVE.
DODIER STR
WRIGHT STR.
ST LOUIS AVE.
EL. 60
EL. 70
EL. 80
EL. 90
East to connection
South to connection
INDICATION
36 inch Pipe.
20 " "
12 " "
6 " "
Pipe Connection
Fire Plug.
Lines of equal elevation
Lines of equal loss of head
Lines of equal "comparative efficiency"
Loss of head for a discharge of 500 Gal. per minute
Comparative Efficiency

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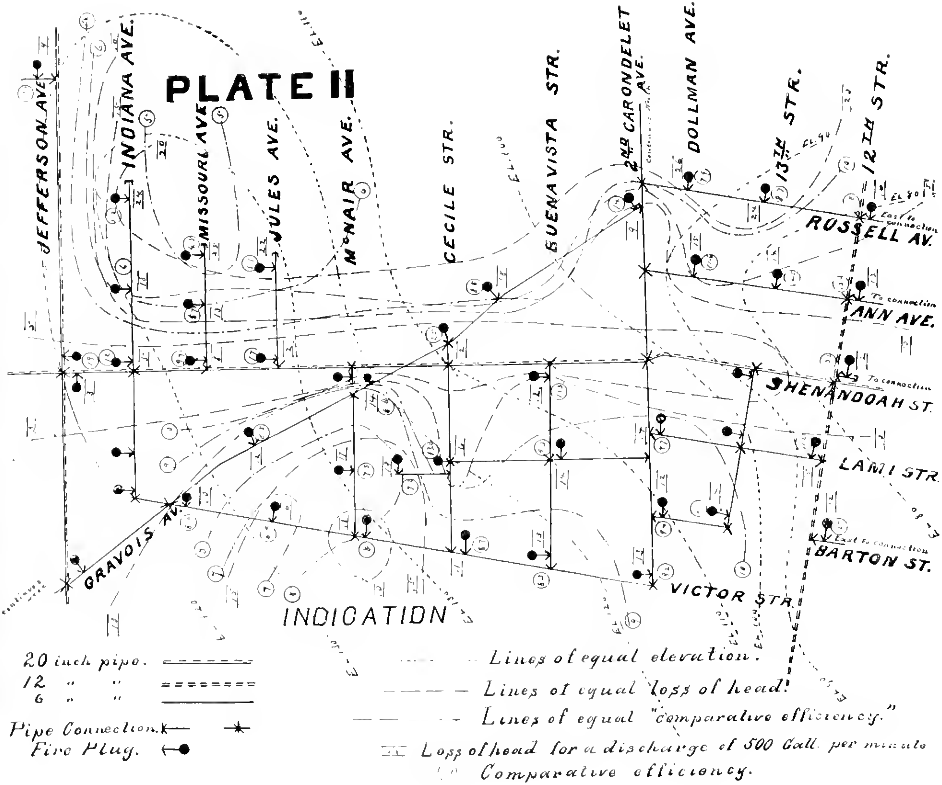


PLATE II
JEFFERSON AVE.
INDIANA AVE.
MISSOURI AVE.
JULES AVE.
McNAIR AVE.
CECILE STR.
BUENAVISTA STR.
2ND CARONDELET AVE.
DOLLMAN AVE.
13TH STR.
12TH STR.
RUSSELL AV.
ANN AVE.
SHENANDOAH ST.
LAMI STR.
BARTON ST.
VICTOR STR.
GRAVOIS AV.
INDICATION
20 inch pipe.
12 " "
6 " "
Pipe Connection.
Fire Plug.
Lines of equal elevation.
Lines of equal loss of head.
Lines of equal "comparative efficiency."
Loss of head for a discharge of 500 Gall. per minute
Comparative efficiency.

TABLE II.

Experiments at Fair Grounds, Dec. 16, 1885, with five fire-plugs.

No. of experiment.	Height of jet in feet. E	Length of jet in feet. A	$\frac{A}{E}$	$22.032\sqrt{2gE(1+R^2)}$ when $R = \frac{A}{4E}$ q	Discharge in gallons per minute measured by meter. q	No. of minutes.	Difference in gallons per minute.	Difference per cent.
1 ...	5½	9½	1.73	452	486	3	34	7.5
2....	6	12	2.00	484	449	2	—35	—7.2
3....	2½	5	2.00	313	292	2	—21	—6.7
4....	13½	21½	1.59	699	688	4	—11	—1.5
5....	14	22½	1.61	712	673	3	—39	—5.5
6.. .	6	12	2.00	484	471	1	—13	—2.7

NOTE.—Experiments Nos. 4 and 5 were made with the same fire-plug.

TABLE III.

Height of jet in feet. E	Discharge in gallons per minute when $\frac{A}{E} = 1.60$. q	Height of jet in feet. E	Discharge in gallons per minute when $\frac{A}{E} = 1.60$. q
1	190	18	800
1½	230	19	830
2	270	20	850
2½	300	21	870
3	330	22	890
3½	350	23	910
4	380	24	930
4½	400	25	950
5	420	26	970
6	460	28	1,000
7	500	30	1,040
8	540	32	1,070
9	570	34	1,100
10	590	36	1,140
11	620	38	1,170
12	640	40	1,200
13	670	45	1,280
14	700	50	1,350
15	720	55	1,420
16	750	60	1,480
17	770	65	1,550

TABLE IV.

Experiments at Old Benton Street Reservoir, Jan. 7, 1886, with one fire-plug.

Co-efficient of Discharge.

No. of experiment.	Head in feet due velocity of discharge, measured by gauge. h_v	$22.032\sqrt{2gh_v}$ = discharge (theoretical). q''	Discharge in gallons per minute, calculated by formula from height and length of jet. q	Co-efficient of discharge $= \frac{q}{q''}$
1........	5.3	405	214	0.53
2........	9.3	538	393	0.73
3........	15.5	695	556	0.80
4........	28	934	879	0.95
5........	36	1,061	962	0.91
6........	60	1,370	1,211	0.88
				0.80 Average.

TABLE V.

Experiments on Cherokee street, Dec. 19, 1885, with five fire-plugs.

Co-efficient of Discharge.

No. of experiment.	No. of fire-plug.	Head in feet due velocity of discharge, measured by gauge. h_v	$22.032\sqrt{2gh_v}$ = theoretical discharge. q''	Discharge in gallons per minute calculated by formula from height and length of jet. q	Co-efficient of discharge $= \frac{q}{q''}$
1..........	2	19	771	564	0.73
2..........	3	20	789	631	0.79
3..........	4	25	881	745	0.85
4..........	5	33	1,015	658	0.65
5..........	6	35	1,046	862	0.82
6..........	2	9	532	374	0.70
7..........	4	10	560	422	0.75
8..........	5	13¼	652	474	0.73
9..........	6	20½	799	653	0.82
10..........	6	20	789	608	0.77
					0.76 Average.

TABLE VI.

Co-efficient of Discharge.

Experiment at Fair Grounds, Dec. 16, 1885.

Head in feet due velocity of discharge measured by gauge. h_v	$22.032 \sqrt{2gh_v}$ theoretical discharge. q''	Discharge in gallons per minute, measured by meter. q	Co-efficient of discharge $\frac{q}{q''}$
23	848	670	0.79

TABLE VII.

Head in feet due discharge in gallons per minute for fire-plug with 3-inch nozzle, co-efficient of discharge = 0.77.

Discharge in gallons per minute.	Head in feet due velocity of discharge.	Discharge in gallons per minute.	Head in feet due velocity of discharge.
200	2.2	800	34
250	3.5	850	39
300	5	900	44
350	6.5	950	49
400	9	1,000	55
450	11	1,050	60
500	13.5	1,100	65
550	16	1,150	71
600	19	1,200	76
650	23	1,300	92
700	27	1,400	106
750	30	1,500	122

TABLE VIII.

Co-efficients to be used with formula $v = \sqrt{2\,g\,E\,(1 + R^2)}$. E = height of jet in feet. A = length of jet in feet. v = velocity of discharge in feet per second.

1. $\frac{A}{E}$	2. $R = \frac{A}{4\,E}$	3. $\sqrt{1 + R^2}$	4. $\frac{\sqrt{1 + R^2}}{1.077}$	Correction to be added per cent.
1.00	0.25	1.030	0.956	—4
1.20	0.30	1.044	0.969	—3
1.40	0.35	1.060	0.984	—2
1.60	0.40	1.077	1.000	0
1.80	0.45	1.096	1.018	2
2.00	0.50	1.118	1.038	4
2.20	0.55	1.141	1.059	6
2.40	0.60	1.166	1.083	8
2.60	0.65	1.192	1.107	11
2.80	0.70	1.221	1.134	13
3.00	0.75	1.250	1.161	16

TABLE IX.

Showing "comparative efficiency" of points on Chestnut street at different dates.

	"Comparative efficiency." Compton ave. fire-plug.	"Comparative efficiency." Cardinal ave. fire-plug.
Before 12-inch line was laid on Compton avenue, Jan. 5, 1885	480	600
Stop-valve shut at Compton avenue, Jan. 15, 1886.	330	370
Twelve-inch line laid on Compton avenue and six-inch stop-valve partly open Jan. 15, 1886	910	790

TABLE X.

Showing "comparative efficiency" of certain points in a system of pipes before and after laying a 20-inch pipe on a neighboring street (Shenandoah street).

Location of fire-plug.	"Comparative efficiency." Jan. 13, 1885.	"Comparative efficiency." Dec. 12, 1885.
Victor street, 2d Carondelet avenue	770	920
Barton street, " "	640	940
Victor street, Buena Vista street	550	830
Victor street, Cecile street	550	870
Lami street, Cecile street	890	1,320
James street, west of Cecile street	500	720
Victor street, McNair avenue	490	800
Victor street, Gravois avenue	470	860
Center street, Gravois avenue	470	850
Ann avenue, Indiana avenue	380	520

TABLE XI.

Sarah street, Jan. 25, 1886.

Test of the formula $h = k\,q^2$. h = loss of head due friction. q = discharge in gallons per minute.

No. of fire-plug.	Gallons per min. discharged. q	Loss of head due friction, etc., in feet. h	Comparative efficiency $= q\sqrt{\frac{52}{h}}$.
1	820	35	1,000
2	860	33	1,083
1 and 2*	1220	52	1,220

* 1 and 2 running together.

TABLE XII.

Test of the formula $h = k\,q^2$. h = loss of head due to friction. q = discharge in gallons per minute. k = constant.

On Finney avenue, Oct. 23, 1885.

Fire-plug No.	1st Experiment. Discharge in gallons per minute calculated from height and length of jet. q	1st Experiment. Loss of head due to friction, etc., in feet for discharge in column 2. h	1st Experiment. Calculated loss of head for 430 gallons per minute $= \frac{430^2\,h}{q^2}$ h_{430}	2d Exp. Measured loss of head for 430 gallons per minute by gauge. h'_{430}
1	990	32	6	5
2	850	46	12	14
3	720	58	21	26
4	680	66	27	30
5	640	68	31	25
6	570	69	40	37
7	520	76	52	46

1st Experiment.—Each fire-plug run by itself.

2d Experiment.—Fire-plug No. 8 running full open and discharging 430 gallons per minute. Losses of head measured at other plugs by gauge.

TABLE XIII.

Experiments on Missouri avenue, Sept. 14, 1885.

Test of the formula $h = k\,q^2$. h = loss of head due to friction, etc. q = discharge. k = constant.

Location of fire-plug.	1st Experiment. Discharge in gallons per minute calculated from height and length of jet. q	1st Experiment. Loss of head due to friction, etc., in feet for discharge in column 2. h	1st Experiment. Calculated loss of head for 300 gallons per minute $= \frac{300^2}{q^2}\,h$. h_{300}	2d Exp. Loss of head for 300 gallons per minute measured by gauge. h'_{300}
Albion pl.	340	62	48	52
Whittemore pl.	390	51	30	28
Lafayette ave.	640	31	7	7

1st Experiment.—Each fire-plug run by itself.

2d Experiment.—Fire-plug at Park avenue running full open and discharging 300 gallons per minute. Loss of head measured by gauge at other fire-plugs.

TABLE XIV.

Farrar St., Feb. 6, 1886.

Test of the formula $h = k\,q^2$; h = loss of head due friction ; q = discharge in gallons per minute.

No. of fire-plug.	Gallons per minute discharged. q.	Loss of head due friction, etc., in feet. h.	Calculated loss of head for 860 gallons per minute = $\frac{860^2}{q^2}\,h$.	Comparative efficiency = $q\sqrt{\frac{72}{h}}$.
1	920	46	40	1,150
2	860	47	47	1,066
1 and 2*	1,170	72	39	1,170

* 1 and 2 running together.

NOTE I.

$$E = \frac{v^2\ sin^2\ i}{2\ g}.$$

$$A = \frac{2\ v^2\ sin\ i\ cos\ i}{g}.$$

$$\therefore sin^2\ i = \frac{2\ g\ E}{v^2},\ sin^4\ i = \frac{4\ g^2\ E^2}{v^4},$$

and $g^2\ A^2 = 4\ v^4\ sin^2\ i\ cos^2\ i = 4\ v^4\ sin^2\ i - 4\ v^4\ sin^4\ 2.$

By substituting, we get :

$$g^2\ A^2 = 8\ v^2\ g\ E - 16\ g^2\ E^2.$$

$$\therefore 8\ v^2 E = g\ A^2 + 16\ g\ E^2.$$

$$\therefore v^2 = \frac{g\ A^2 + 16\ g\ E^2}{8\ E}.$$

Let $\frac{A}{4\ e} = R. \quad \therefore A^2 = 16\ E^2\ R^2;$

then $v^2 = 2\ g\ E\ R^2 + 2\ g\ E$

$= 2\ g\ E\ (1 + R^2),$

and $v = \sqrt{2\ g\ E\ (1 + R^2)}.$

When $A = 0$, $R = 0$ and $v = \sqrt{2\ g\ E}.$

NOTE II.

I. Assume a pipe connecting two reservoirs.
Let H = difference of level between the reservoirs.
Let q = quantity of water discharged through the pipe.
If the pipe be composed of three sections, assume in the first section,

h' = loss of head in first section and that $h' = a\ q^2$.

In the second section,

h'' = loss of head in second section and that $h'' = b\ q^2$.

In the third section,

h''' = loss of head in third section and that $h''' = c\ q^2$.

Assume a, b and c constant.

Then $H = h' + h'' + h''' = (a + b + c)\ q^2.$

Hence, if it be true that in a line of pipe having the same section throughout, the loss of head due to friction is proportional to the square of the discharge, it must be true in a pipe of varying section.

II. Assume three lines of pipe, each of uniform section throughout, connecting two reservoirs. Let h = difference of level between the reservoirs.

In the first pipe,

Let q' = quantity of water discharged, and let $q' = \frac{1}{\sqrt{a}}\sqrt{h}$.

In the second pipe,

Let q'' = quantity of water discharged, and let $q'' = \frac{1}{\sqrt{b}}\sqrt{h}$.

Let, in the third pipe,

q''' = quantity of water discharged, and let $q''' = \frac{1}{\sqrt{c}}\sqrt{h}$.

Assume a, b and c constant. Then

$$Q = q' + q'' + q''' = \left(\frac{1}{\sqrt{a}} + \frac{1}{\sqrt{b}} + \frac{1}{\sqrt{c}}\right)\sqrt{h}.$$

Hence, if it be true that in a single line of pipe the loss of head is proportional to the square of the discharge, it must be true for any number of pipes having a common supply and discharge.

Combining I. and II., it may be shown that in any system of pipes having one supply and one discharge, the loss of head is proportional to the square of the discharge.

The formula given by Weisbach for a curve or bend in a pipe is

$$h_c = \frac{\varphi}{180}\left(0.131 + 1.847\left(\frac{r}{R}\right)^{\frac{7}{2}}\right)\frac{V^2}{2g}.$$

h_c = head lost by resistance in curve in feet.

φ = deflection in degrees.

$r = \frac{1}{2}$ diameter of pipe in feet.

R = radius of axis of pipe in feet.

V = velocity in feet per second.

The formula given by D'Aubuisson (Bennett) for the resistance of a reducer is

$$h_r = 0.251817\frac{Q^2}{D^4}\left(\frac{1}{m^2} - 1\right).$$

h_r = loss of head in reducer.

D = diameter of first pipe.

m = co-efficient of contraction.

Q = discharge.

If the same curve or reducer be taken, both these formulæ may be reduced to the general form:

$h = k\,q^2$.

When h = loss of head.

q = discharge.

k = a constant.

DISCUSSION OF MR. RUSSELL'S PAPER, FEBRUARY 17, 1886.

Prof. Woodward : Mr. Russell, in testing your formula, have you or any one turned on a number of fire-plugs in a district and observed them simultaneously?

Mr. Russell : I made two experiments of that sort with two fire-plugs.

Prof. Woodward : I know you give two, but is it not feasible to have all tried in case of a fire?

Mr. Russell : The only case that I know of its being done was after a rather disastrous fire on Park avenue, where a car stable burned down. The pressures were all good and the pipes seemed to be amply sufficient for fire service, but after the fire I turned on all the plugs at which en-

gines had been, and found that when sufficient water was running from the lower fire-plugs, no water was to be gotten from the higher ones.

Prof. Woodward : How many were turned on in that experiment?

Mr. Russell: Only six. They were located on very high ground.

Mr. Whitman : What is the size of the pipes in that district?

Mr. Russell : There is a 20-inch line on Lafayette avenue, and from that six-inch pipes as far north as Chouteau avenue. This district lies between Park avenue and Chouteau avenue, Second Carondelet avenue and Lafayette avenue.

Mr. Whitman : In the case you speak of, did not the trouble come on the dead end pipe in the alley back of the stable?

Mr. Russell : Yes. That was where the engines did not get water. There were two engines trying to get water from that dead end pipe.

Mr. Whitman : It comes about as much from the laying out of the subdivision as anything else. The pipe you speak of was laid in the rear of the stables and left with a dead end. Since that time I believe they have extended the pipe across the lot over into Park avenue, so that the pipe is well supplied.

Mr. Russell : I would say in this connection that in experimenting with a number of fire-plugs at different elevations you would probably get large streams from some and none at all from others ; that is, if the plugs were full open, and as I have made no experiments with a plug partly closed, I do not know how it would affect the co-efficient of discharge of the fire-plugs. We always open the plugs in full. In that way we know the co-efficient.

Prof. Johnson : In your paper you spoke of the co-efficient being variable. That would depend a good deal on the condition of the plugs, would it not?

Mr. Russell : The plugs experimented with were in good order. Some very startling results were obtained from experiments on the Missouri avenue line, a six-inch line laid about six years ago. I plotted the hydraulic grade line for it, and found that it had a slope about three times as great as Kirkwood's table would give. We found it necessary to shut the stop valve at one end of this line, in order to maintain pressure for domestic purposes. With the stop valve shut we would get a jet from the fire-plug on corner of Missouri avenue and Park avenue, three feet high, and with the valve open a jet of about 18 feet high. The stop valve is on the south side of Park avenue. The Missouri avenue line connects with a 20-inch pipe on Lafayette avenue and a 12-inch line on Park avenue. We had the valve shut at the connection with Park avenue, preventing any water from coming from Park avenue main. Park avenue is in the lower district and Lafayette avenue in the upper district.

Mr. Taussig : Was there a greater demand on the Lafayette avenue main than on the Park avenue main?

Mr. Russell : No. But if you shut the stop valve at Lafayette avenue it makes it worse still.

Mr. Moore : How do you account for the loss of head by friction in that pipe being three times the loss of head as shown by Kirkwood's table?

Mr. Holman: Well, the formula does not apply to that pipe, because the conditions are not similar to those in the experiments from which the formula was derived. Formulæ for flow of water in pipes generally express the results of some experiment or a number of experiments. Now engineers are apt to take some formula and apply it to everything in the way of pipe, when in reality that formula applies only to cases similar to those which obtained in the original experiments. I will state here that in a very careful experiment made on a long line of 6-inch pipe, Colonel Flad had open top mercury gauges constructed and connected with the pipe at various points. The water discharged was received and measured in a large cistern. Gauge readings were taken every ten minutes during the discharge. These were afterwards plotted and the hydraulic grade line was found to be perfect. At the same time the quantity of water discharged per minute was one-third of the quantity calculated by Kirkwood's formula for tuberculated pipe.

Prof. Johnson: Was there not some obstruction in the pipe—a valve partly closed, or something of that sort?

Mr. Holman: In this case we had a long line of 6-inch pipe running under constant head and discharging into a cistern. We put mercury gauges at regular intervals along the pipe. The gauges indicated the pressure in the pipe. Now, if there is no obstruction in the pipe, the hydraulic grade line given by the gauge readings will be a straight line, but if there was at any point a stick or some other obstruction in the pipe, you would find the grade line would not be straight. This pipe gave a perfectly straight hydraulic grade line. At the same time, the discharge was only one-third of what it should have been by Kirkwood's formula.

Prof. Johnson: What is the basis of Kirkwood's formula?

Mr. Whitman: I may say that Mr. Kirkwood's formula was obtained from experiment on the mains between Jersey City and Hackensack. Also experiments were made on the New York mains from the reservoir down to Canal street and then on a line in Brooklyn.

Mr. Seddon: Have you any idea what the diameter was in those experiments?

Mr. Whitman: It varied from 20 to 36 inches.

Mr. Seddon: That would account very readily for the difference.

Mr. Holman: Well, hardly; some of the formulæ for flow of water in pipes were derived from experiments on small pipes, one inch and less. Kirkwood's formula gives a very great loss of head, but in this case it was not large enough. The pipe was what is known as a 6-inch pipe. In casting pipe they of course cannot cast them 6 inches, or any other dimension exactly; they are generally a little more or a little less and that difference seems to be greater in large pipe. I have found pipe that were classed as 36-inch pipe that measured 36½ inch internal diameter. The 6-inch line I spoke of was laid by people that never before or since laid a line of pipe, and undoubtedly it was laid very badly. It is the line connecting Grand avenue with the Insane Asylum, and I think a great deal of trouble comes from the way it was laid.

Prof. Woodward: Are there any accumulations in the water pipe?

Mr. Whitman: Well, not in the mains to any extent; that is, the current keeps them pretty clear. There was one pipe that we took out on Fourteenth street in connection with some bridge extension or something of that kind. The pipe was over half full of mud, showing that the pipe had very little to do. But laterally in cutting out for connections we have not found any mud in the mains.

Prof. Johnson: I would like to learn further in reference to what Mr. Russell said about the Missouri avenue main.

Mr. Whitman: We have changed that by putting in a check valve there so that when the fire-plug is opened the check valve opens and gives a supply as wanted, so that we have a high domestic pressure and a good fire service.

Mr. Taussig: The pressure is less on Waverly place, for the same height, than it is on Preston place. How do you account for that?

Mr. Whitman: I suspect your neighbors are wasting water.

Prof. Johnson: I am called upon sometimes to advise in regard to what formula to use in case of pipes, and I have relied in my own mind on the experiments and paper by Hamilton Smith, of the American Society of Civil Engineers. I would like to ask your judgment of that paper and if there is anything better.

Mr. Holman: The formulæ generally accepted by the Germans and Austrians, who have probably given the subject more study and attention than any one else, are the formulæ of D'Arcy, Prony and Weisbach

In some experiments that were made in Germany, these formulæ were shown to be very accurate. But at the same time they gave a loss of head by friction differing from the results obtained by Smith, and a much greater loss than was obtained from a 48-inch pipe, by F. P. Sterns.

The co-efficient in that case was very low. Whether that came from the pipes being a little larger than 48 inches or the special quality of the laying I do not know.

Mr. Moore: Was that a cast-iron or wrought-iron pipe?

Mr. Holman: It was a cast-iron pipe.

Mr. Moore: Mr. Holman, what is the relative friction of wrought-iron and cast-iron pipe?

Mr. Holman: A large wrought-iron pipe will have a higher co-efficient than a smooth laid cast-iron pipe, unless laid with butt joints, on account of the joints. A good cast-iron pipe well coated and properly laid should give as small a co-efficient of friction as any pipe.

Prof. Johnson: You are obliged to use something in designing a new system. You are obliged to use some formula. What would you use?

Mr. Holman: Well, I would use the formulæ mentioned, but would also arrange to increase the head on the pipes if necessary.

Prof. Woodward: I would ask if in those observations on the long 6-inch pipe there were any changes in the pressure.

Mr. Holman: Yes, there was a pulsation on all the gauges from one end of the pipe to the other.

Prof. Woodward: Where was the water taken from?

Mr. Holman: Out of the reservoir.

(Mr. Holman here made a diagram of the experiment on the long line

giving positions of the gauges; etc., said): There was a distinct pulsation on all of the gauges.

Member: Was the stand-pipe between this pipe and the pumps?

Mr. Holman: Yes: and we had from 3 to 5 inches pulsation of the mercury.

Prof. Woodward: Was there any secondary motion?

Mr. Holman: Yes, there were secondary pulsations, but I do not remember to what extent.

Mr. Whitman: In some experiments at the stand-pipe made by Fred Rice in regard to pulsations he recorded that they were from five to eight feet and were from two to three per minute.

Mr. Holman; You could have these two or three primary pulsations of the stand-pipe and also any number of secondary ones.

Prof. Johnson: How long was that 6-inch pipe?

Mr. Holman: About two and one-half miles.

Prof. Johnson: Is there not a great dearth of actual experiments on various sizes of pipes for various lengths when you come to take long lengths?

Mr. Holman: So far as I know there are very few experiments on long lines.

Col. Moore: I would like to ask a question about that Insane Asylum pipe. You say it was laid by the county, and it was intended to deliver water to the asylum? Don't it do it?

Mr. Whitman: I do not know. They say that it don't. They want to use about 100,000 gallons per day, and very seldom they say is the quantity more than 50,000 or 60,000.

Prof. Johnson: I think Mr. Bryan has an interesting point in regard to cleaning out the oil pipes. He is in the pipe business.

Mr. Bryan: I noticed in an article a short time ago that they have a little scraper which they put in the oil pipe lines to the seaboard in the East. They have relays of pipe-men whose business it is to follow it up hill and down. They must never let it get out of their hearing. It makes a sort of clattering noise, so that they can locate it. If they lose track of it, it is a great job to know where to clear the pipes again.

Prof. Johnson: What is the nature of the deposit.

Mr. Bryan: I do not know, but think it is an oily gummy substance.

Member: How fast does the scraper travel?

Mr. Bryan: The men are able to keep up with it. They have relays of men stationed along the line who take turns in following it.

BEACON STREET RESERVOIR—LOWELL WATER-WORKS.

By George E. Evans, City Engineer, Lowell, Mass.

[Read March 17, 1886.]

Before describing the accident that happened to the reservoir last fall, it may be well to give a brief description of the reservoir and the method of construction. The reservoir is situated at the head of Sixth street, on Beacon street, and is about 150 feet above the central portion of the city. Its shape is nearly square, excepting that the two easterly corners are cut

off. The perimeter of the embankment incloses 7.1 acres, and the perimeter of the top of the embankment on the inner line measures 1,852 feet. The high-water surface covers 5.2 acres, and the reservoir contains 30,500,000 gallons when the depth is 20 feet. The embankment is 15 feet wide on top, and the interior slope is 1½ to 1, and the exterior slope is 2 to 1. It is 24 feet from the top of the embankment to the bottom of the reservoir. The southeast side is mostly embankment, the northeast is excavation, and the remaining sides are about equally divided between excavation and embankment.

The material under the top soil is technically known as "hard-pan." It was so hard that it could not be picked advantageously, and a special steel plow was procured, and six oxen were required to do the plowing. The embankment was made in the usual manner from the excavation, and carried up in layers six inches in depth, and all stones larger than four or five inches in diameter were taken out. Each layer was thoroughly wet and rolled with a heavy grooved roller. The inner slopes were made with an extra width of one foot, which was afterward dressed off to receive the puddle lining. The inside slopes are lined with puddle two feet thick, and extend under the base course and join the bottom puddle, which is one foot thick. The puddle was selected from the excavation, and laid on the slope in layers six inches thick, and wet just enough to bind it together without bulging, and thoroughly rolled with small cast-iron rollers. The lower half of the slope is covered with a layer of broken stone eight inches thick, and the upper portion with a twelve-inch layer. The granite slope paving is laid dry upon the broken stone, the joints being carefully pinned with spauls. The thickness varies from twelve to fifteen inches. On the bottom, at the foot of the slope paving, a skew-back or base course was laid three and one-half feet wide and eighteen inches thick, which rests upon the puddle. The reason the puddle was placed on the slope and connected with the bottom puddle, instead of in the center of the embankment, was on account of small sand seams being found in the test pits, which were feared would cause leakage. No leakage has ever been discovered.

The reservoir was completed October 1, 1872, and water was let in the last of November of the same year. For a period of thirteen years the reservoir had not been cleaned out, or the water allowed to be less than eleven feet deep; and it was decided to draw the water off, and clean out the mud. To draw the water from the reservoir, the pump was stopped September 26, 1886, and the water allowed to subside by city consumption, which was at an average rate of 0.98 inch per hour.

The depth of water in the reservoir was 19½ feet. At 3 P. M., October 2, the granite paving on the north slope started, and slowly slid down, making a diamond shaped breach 150 feet in length, and 8 feet wide in the widest part. October 4, at 3 P. M., a section of the paving on the west slope, adjoining the gate-house on the south side, about 157 feet in length, slid down, and, carrying a large quantity of the broken stone and puddle, piled up on the bottom of the reservoir. There were about 600 square yards in this slide, and one-half of this amount pushed the base course horizontally into the reservoir about ten feet, and the upper portion rolled down upon it. The portion adjoining the gate-house only

LOWELL WATER WORKS. NOV. 1885.

pushed the base course out a short distance and slid down in a body, leaving a gap in the slope.

The water at this time was about 4 feet 10 inches deep. The next forenoon at eleven o'clock a section of paving on the west slope. north of the gate-house, 150 feet in length, slid slowly into the reservoir, about 24 feet from the foot of the slope, plowing up the bottom before it. (See sections.) The water was about 2 feet deep. This slope was examined by the writer about an hour before the accident happened, and it showed no signs of starting and gave no warning before sliding, but moved in a body, slowly down the slope, similar to wet snow sliding on a roof. The embankment was so thoroughly saturated with water that the puddle acted as a lubricant, causing the paving to slide, and the bottom had become so soft that it offered no resistance. The bottom puddle was so soft and miry that a person walking on it would sink about one foot, although there was a thin crust which would bear one up for a short distance. In no case did the slides break back of the original face of the slope in the rear of the puddle lining, and above the original surface (base of embankment) the puddle remained nearly the same as laid. The material at the first appearance seems to have considerable clay, but an examination by Mr. W. P. Atwood, chemist, revealed the fact that it is composed largely of fine sand mixed with gravel. It contains about eleven per cent. of oxide of alumina.

A large gang of laborers was set to work, and all of the soft and miry puddle on the slope was taken out and the space filled to the line of the broken stone with fine bank gravel, as far up the slope as a line about two feet below the base of the embankment, and all places above this line that required filling were filled with gravel mixed with one-third of the old puddle. The plan of relaying the paving was changed, and instead of having a base course level with the bottom, a trench was excavated 5¼ feet deep and at a angle to the slope (see section). The bed stones varied from 3½ to 5 feet wide and from 12 to 18 inches thick ; and the second course was about 2½ feet wide and 15 inches thick. These courses were laid in cement mortar and at a right angle to the slope paving, which was laid dry upon a layer of broken stone from 8 to 12 inches thick. Near the southwesterly corner quite a section of paving remained in place, and to prevent this from sliding a trench 3 feet square was dug along the base course and filled with cement concrete.

The northeast slope, which was bulged by the pressure of springs in the side-head about midway down the slope soon after the reservoir was completed, and before water was let in, remained in place without showing any change. The bulge in the highest portion is from 5 to 7 inches. The base course had been pushed horizontally into the reservoir a few inches, and the outer course was slightly raised. It appeared as having been done a considerable time before the accident to the other slopes. It was considered unsafe to disturb the base course, and to prevent any further movement a dry rubble wall 8 feet wide and 4 feet high was laid on top of it and overlapping the puddle bottom.

The other slopes remain as originally laid, excepting a slight settlement or falling back of the paving at the top.

The first stone of the foundation course was laid October 22, and the

paving was laid up to a height, November 8th, so that four feet of water was pumped into the reservoir, which was increased as the paving progressed. The paving was all relaid November 30, making thirty one days to complete it.

While the work was being done the city was supplied with water by pumping through the gate chamber, which is so arranged as to serve the purpose of a stand-pipe, and no difficulty was experienced. Its available capacity is about 25,000 gallons.

SMOKE PREVENTION.

REPORT ON THE ADAPTATION OF THE WILLIAMS FURNACE TO ONE OF THE BOILERS OF THE HEATING PLANT OF WASHINGTON UNIVERSITY, ST. LOUIS.

About a year ago Mr. Jacob S. Williams was authorized to adapt one of his smokeless furnaces to one of the battery of boilers that supplies the steam for heat and power to Washington University. The work was to be done by Mr. Williams at the expense of the University, and under the direction of the undersigned. The apparatus was not ready for trial till June, when, just preceding the close of the college year, three days' trials were had of seven hours each. The trials were to determine the capacity, economy and smoke-preventing qualities of the furnace.

These trials were fairly satisfactory, so far as economy and smoke-prevention were concerned. The economy was about the same as with the old furnace (which has always been considered very good), and the chimney was practically smokeless, except when the doors were opened for feeding. With a good automatic feed the chimney could readily be made smokeless. In the matter of capacity, however, the June tests had been far from satisfactory, the maximum attained being 22 pounds of coal per square foot of grate surface per hour, or 3.38 pounds of water evaporated per square foot of heating surface per hour. The old furnaces may be made to burn 36 pounds of coal per square foot of grate surface, and evaporate 5.70 pounds of water per square foot of heating surface per hour. Thus the *capacity* of the Williams furnace was but about 60 per cent. of that of the old furnaces, while the efficiency was about the same and the smoke record very good.

It is proper to say that Mr. Williams' device embodies a forced draught, and this has to be supplied by an auxiliary engine. The University did not have an engine well suited to this purpose, but, on application to the Westinghouse Machine Company, at Pittsburgh, a suitable engine was loaned us with the privilege of purchasing at a very low figure in case we should wish to retain it. With a larger boiler and furnace capacity the Williams furnace could be used and the smoke eliminated at a small increased cost of fuel to provide for the forced draught. A capacity of twenty pounds of coal per square foot of grate surface per hour, or of some three and a half pounds of water per square foot of heating surface, is considered a fair service, but the demands on our plant are so great that nearly twice these amounts must at times be realized. This seemed to be the limitation, therefore, that would prevent our using the Williams furnace unless we doubled our furnace and

boiler capacity, and it was mainly in this direction that the committee have turned their attention during the current year.

The Williams furnace provides for a constant supply of air below the grate bars, and a variable supply above, the maximum supply over the fire coming with a fresh supply of coal to mix with the more volatile hydro-carbons that are suddenly driven off, and which cause the dense volumes of black smoke from fresh fires in the ordinary furnace. In fact, all the conditions of perfect combustion with greatest economy are present in the Williams furnace, and all are under control. It was this extended compass of the Williams design which caused the committee to feel that, when properly regulated, it ought to give as good results as could be secured with a perfectly smokeless furnace; and within its proper capacity, we still feel that this impression was correct. The apparatus used by Mr. Williams for varying his air supply over the fire was complicated and unsatisfactory. The committee succeeded in simplifying this part of it very much.

The final and test question then was: How can the capacity of this furnace be increased? The cause of the diminished capacity was evident. With a given chimney draught there is a given difference in atmospheric pressure above and below the fire. This difference in pressure is what causes the air to force its way through the obstructing bed of coals, and so supply the oxygen necessary to the consumption of the fuel. The amount of coal consumed is therefore directly in proportion to the air passing through the fire, and this in turn is proportional to the difference in pressure above and below the bars. If now we have two furnaces connected with the same chimney, one having no air supplied above the fire and the other having about twice as much air supplied above the fire as there is coming through it (as is necessary for complete combustion), it is evident that the diminished atmospheric pressure above the fire, due to the chimney draught which is common to the two, will be largely supplied by the over-air supply in the second case, and that there will then be a much less draught through the coal bed. The coal consumption will therefore be cut down. Thus, while the old furnaces will burn 36 pounds of coal per square foot of grate surface per hour, the same furnace, with a sufficient supply of air over the fire to prevent smoke, will burn but 22 pounds. There are now but two feasible ways to bring up the consumption of the second furnace, and they are either to increase the height of the chimney or to increase its draught by a fan in the flue. To increase the combustion from 22 to 36 pounds would require more than 100 feet increase in the height of our chimney if the increased combustion is to be accomplished by this means alone.

Some experiments were tried of forcing the air through the coal bed by introducing a greater than atmospheric pressure under the grates, but then with an increased consumption of coal it was necessary to increase the supply of air above the grate again, if smoke was to be prevented, and when this was done the pressure over the fire became greater than atmospheric, and the fire was forced out at the doors. Evidently a genuine *forced* draught applied at the furnace cannot be attained in a practical way except by keeping the air in the boiler room at greater than atmospheric pressure. This is done on some steam vessels, but would be impractical in our case.

In January the Westinghouse Company called back their engine, and as the arches of the Williams furnace had forced out the side walls somewhat, thus necessitating their being torn out, the committee decided to let the engine go (in place of recommending its purchase at the small price of $100). The arches were then torn out and the furnace rebuilt very much as it was before.

While the Williams device has proved insufficient for our purposes, we cannot look upon the experiment as without valuable results, nor do we think the money and labor spent upon it as in any sense wasted or misplaced. The smoke nuisance is becoming intolerable, and our chimney is almost as bad as the worst. Thousands of dollars are being spent in many and various directions towards its abatement. Every fact of general application which may be tributary to the final solution of the problem is of great value, and is worth paying for. We feel that we can make such a contribution to the present accepted theories on this subject.

1. It has been generally asserted that if the smoke is eliminated there results a loss in *economy*. This we have found is not necessarily true. That where the proper amount of air is supplied in the right manner, the smoke may be entirely prevented with no loss in economy.

2. It has been generally surmised, and known in a general way by experts, that a supply of air above the grate bars would result in a loss in capacity, but as to what would be the *amount* of this loss, we have never seen any statement. *This we have determined for our furnace*, and in an approximate way for *all furnaces*. Thus, for our furnace, we have found that the *extreme capacity* was reduced *forty per cent.* by the supply of air above the grates sufficient to prevent the smoke. We are also able to say, with confidence, that *in any case*, the *extreme* capacity will be reduced in *about this ratio*, and that, therefore, any smoke-preventing device, which at the same time gives complete combustion (for the two are not necessarily coincident), cannot be used with a plant that needs to be worked to its extreme capacity in the ordinary way, without at the same time nearly *doubling* the *force* of the chimney draught by some means or other, or else nearly doubling the size of the plant.

This is a general proposition of universal application. If a given plant only needs to be worked ordinarily to about sixty per cent. of its extreme capacity, the smoke could be here eliminated without loss in economy, and without any extension of chimney or plant But where, as in our case, the plant needs to be worked at times to its extreme capacity, we could not, *at such times*, work any smoke preventing attachment, At all times, however, when the demand is at or below 60 per cent. of the extreme limit, then the smoke could be prevented, even from our furnaces, without any additional extensions. The limitation, therefore, is not in a loss in *economy*, but in a serious loss in *capacity*.

These specific generalizations we have not met with in all the literature on this subject that has come to our attention, and they are of great and fundamental importance in the solution of the perplexing problem of smoke prevention.

There are, in general, four ways in which to recover the capacity lost from the supply of air above the fire.

1st. To extend the chimney sufficiently to about double the *force* of the draught, or to double the amount of "vacuum" in the flue.

2d. To put a fan, or blower, in the flue, and so increase the draught.

3d. To increase the pressure in the boiler-room above the outside atmospheric pressure.

4th. To increase the furnace and boiler capacity.

The third method is hardly feasible with land stationary boilers. One of the other three alternatives will have to be resorted to, therefore, before we can hope to prevent the smoke from our chimney in the winter season.

Signed by

J. B. JOHNSON,
C. F. WHITE, } Committee.
C. K. JONES,

ST. LOUIS, March 23, 1885.

To the Chancellor of Washington University.

RAILROAD WASHOUTS.

BY CHARLES W. FOLSOM, MEMBER OF BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read April 7, 1886.]

For the last two years my attention has been attracted by the very large number of railroad washouts reported in the newspapers. Taking the trouble to cut out the paragraphs, when they happened to catch my eye (but making no search for them), I have got a collection of 50 items,

DATE.	State.	Name of railroad or place.	Rainfall reported. Inches.	Number washed out. Bridges and culverts.	Number washed out. Miles of track.	Lives lost.	Money damage reported.
1881.							
Feb. 10....	Ohio & Ind.	Wabash.	60 hours	14	...	...	$175,000
March 26..	Nebraska.	U. Pacific.	...	1	$1\frac{1}{2}$	...	...
April 11...	California.	Oregon.	...	1	...	2	...
1883.							
Sept. 8....	Texas.	Mexican.	...	11	Several.	...	...
April 7....	Louisiana.	*N. Orleans.	$5\frac{5}{8}$	...	...	...	...
1884.							
April 15...	California.	Southern.	...	5	4 in places	...	250,000
May 22....	Texas.	Many.	Many.	Many.	...	...	...
May 18....	Kansas.	U. Pacific.	...	1	$\frac{3}{4}$	70 cattle.	...
June 11....	Penna.	†Cumb. Val.	...	1	$\frac{1}{2}$	...	...
June 10....	Nevada.	C. Pacific.	...	...	30 in pl'es	...	...
Sept. 16...	Wisconsin.	‡M. & St. P.	14	19	10 in pl'es	...	200,000
Oct. 5......	Minnesota.	Duluth.	...	1	...	3	...
Oct. 2 ..	Wisconsin.	No. Wis.	...	1	...	6	...
May to Oct.	Col. & N. M.	§A., T. & S. F.	...	Many.	Many.	...	330,000
1885.							
July 19...	New Mex.	A., T. & S. F.	...	1	...	4	...
July 31....	Vermont.	P. & O.	...	1	...	2	...
July 29...	Mass.	¶Lowell.	$4\frac{3}{4}$	...	...	...	...
Aug. 3.....	Illinois.	Chicago.	$5\frac{1}{2}$	...	...	...	...
Aug. 14 ...	New York.	N. Y. C.	4	1	...	...	25,000
Aug. 31..	Illinois.	Wabash.	...	1	...	1	...
Sept. 28....	Florida.	...	10	...	...	...	...
Sept. 25....	Mexico.	Central.	...	...	10 in pl'es	...	...
Nov. 3.....	Vermont.	B. & W.	...	1	...	1	...
Nov.	New York.	West Shore.	...	...	...	1	...
1886.							
Jan. 22. ..	Penna.	...	...	...	...	2	...
Jan. 22 ..	California.	So. Pacific.	5	Many.	Many.	...	150,000
Feb. 12-15.	Mass.	**Boston.	6	Many.	...	...	300,000

* "In $3\frac{1}{2}$ hours." † "Passenger train just saved by a farmer." ‡ "Railroad from Eau Claire to Wabasha almost obliterated." § "Rio Grande left its channel and attacked the road-bed." ¶ Official report. ** Official report of rainfall, Boston waterworks.

recording the loss of nearly 80 bridge spans and about 125 culverts, involving the death of 32 employés and 2 passengers, with injuries to many others; and with a property loss only to be counted by millions, two items alone recording a united loss of half a million dollars.

The accompanying table gives a connected view of some of the most striking of these newspaper items. (The statements of rainfall, of course are mostly from unofficial sources, and have only a limited value.)

If this is a fragment of the after-breakfast reading of one engineer in a Boston newspaper, the annual result in the United States can be very moderately set at 40 bridges and 50 culverts washed away, with 20 lives and $1,000,000 worth of property destroyed. Probably accurate statistics would go far above that.

It may be worth while to consider what this large loss of life and property is owing to, and what can be done to prevent it.

Perhaps it would not be too much to say that the railroad work of a good engineer, well supplied with funds, should be water-proof against all ordinary storms, or even against all ordinary great storms. At least, it is well to make it so, not only for humanitarian reasons, but as a matter of economy; no washout from ordinary great storms can be cheaper than the precautions necessary to prevent it *in that one place*.

But if we are going to attempt to make our whole line storm-proof, there comes in at once the consideration of water-spouts or "cloud-bursts," abnormal bursts of rainfall, by which many inches of water are precipitated in a very few hours, or less time, over a limited area. It is alleged that these sometimes come in such extraordinary proportions as to entirely sweep away all outlets arranged on usual principles; and that the "insurance outlay," which would be necessary to guard *all* crossings of streams against these extraordinary dangers, would bankrupt all ordinary railroad companies.

I have not been so fortunate as to find any reliable or scientific quantities, times, etc., of these "cloud-bursts" in the States west of the Mississippi River (from which region the accounts of them have been most numerous), and I have had no personal experience of them in those regions. But if the mountain streams in the Alleghany or "Appalachian" range are an index to the behavior of their western sisters, it is difficult to see why the tracks of the Pennsylvania, the Baltimore & Ohio and the Chesapeake & Ohio Railroads have not been washed away by the water-spouts as well as those of their sister roads further west. If the height of the freshets in the main streams can be taken as an indication of the violence and suddenness of the rainfall, the Alleghany, the Monongahela, the Kanawha and the Cumberland set a pretty high standard. The Ohio, at Cincinnati, and the Tennessee, at Chattanooga, have both risen 60 feet above low water within my personal knowledge. Is it possible that rapidity or cheapness of construction of the roads further west can have had any bearing on their losses from the floods?

I am strongly of the opinion that the subject of "water-way," or the proper provision for the passage of streams alongside and under the road-bed, has not always received the attention which its importance demands. The water-way of large streams has sometimes been contracted in order to shorten the bridge spans. Grades have been kept

down close to the "freshet mark" to save embankments and masonry. Culverts have been "sprinkled in" where well-defined streams presented themselves without much inquiry as to how large a district they drained, or whether every small source of water coming against the track was provided for.

It has been my fortune several times, by one accident or another, to be called on to take charge of a portion of railway construction commenced by another engineer. In every case, on going over the line, profile in hand, my first and imperative duty has seemed to be to *increase the number and size of spaces for water-way.* Perhaps this may have been the fault of an over-worked chief engineer, forced to get his principal knowledge of the line in the office; or of a young assistant, who, though bright and accomplished, had never seen the destructive effects of a freshet. I confess my own first and early lesson was a sharp one, when I waked up one fine morning to find a 4-foot box culvert and embankment "*clean gone*," which (though not responsible for its design) I had never dreamed was insufficient. A 6-foot arch was the immediate successor of the 4-foot box!

If we are planning a sewer or conduit near one of our great cities, our first task is to ascertain the area, slope and character of tributary watershed: and by some allowance (possibly with uncertain data, but on fixed principles) compute the needed size of our water-bearing tube or canal. The lack of accurate maps or other information has often prevented any close attempt to do this in railroad work; but efforts in the direction of such calculations would often be well rewarded.

Among some of the precautions against the loss of open-span bridges which may be briefly hinted at are first, as to *span*: to remember that if the cross-section of the *piers* be deducted from the water-way we must set our *abutments* well back on dry land, in order to preserve the original area of cross-section (and luckily this often gives a distinct offset to the greater cost of the superstructure by a saving of masonry and expense in foundations). If the stream has wide bottoms, the chances are that side spans, "dry land spans," or trestle-work will be needed back from the stream.

Second, as to *Grade*: a "freshet mark" is at best a rather doubtful record of what *has been*, and by no means a perfect assurance of what *may be*. If the region above our bridge is thickly wooded we may have a large tree, branches and all, swimming out of water to catch our lower chord; if it is a farming district a big barn, with fifty cords of fence rails, may give us a severe pull. Six feet above freshet mark is a great deal better than one. Often we may do as our ancestors did with their highway bridges—set them up high and dry, giving plenty of head-room above the flood, while the long approach of embankment can be kept several feet lower. In exceptional cases of moderate span, the *hanging* of the floor-beams gives us a foot extra room.

A stream is often diverted into a channel alongside the track in order to save two bridge crossings; and as many of the serious money losses come from long embankments washed away by a river *alongside*, it is possible that attention enough is not always given in the diversion of a stream to making a curved entrance to the diversion; with a dam between

such entrance and the track, in order to keep the force of the stream when in freshet from impinging upon the embankment on its original line.

But while a treatise might be written on the various considerations affecting the span and height of open bridges, the diversion of rivers, and the protection of embankments by riprap or otherwise against rivers, and while it is probable that the larger part of the *money loss* comes from defects in this branch of railroad water-way; yet I think that most of the *accidents to trains* and loss of life come from defects in the number, size, or construction of small culverts. A big bridge will rarely go without sufficient notice to save the trains; but a small culvert may give way in the night without a moment's notice.

If a culvert is too small, or if the waterspout is abnormally large, the culvert will have to run *under a head*. But few of the culverts of the old school were constructed fitly for that end. Many of us can recollect seeing those that were little better than a mass of dry rubble pitched into a hole, and covered up as quickly as possible. The very excellence of our New England granite as a building material tempted to its use without cement. Now-a-days probably few new culverts are built or old ones repaired except with full beds of cement.

If a culvert has got to take the risk of running under a head the foundation will be the important point. Nothing can be better than timber or plank foundations in soft, wet ground, with a row of sheet piling driven ACROSS the axis of the culvert at both the upper and lower ends. In hard ground a paving of the most tightly packed blocks with a "sheet piling" of flag-stones set edgewise should be used. In some districts thin flags are so plentiful that a 3-foot or even a 4-foot culvert can be paved with a solid floor of flags extending well under both walls.

The nature of the embankment over and around the culvert is important. If it is composed almost entirely of large loose fragments of rock (as may easily be the case near a rock cutting, if not looked after), it will indeed, perhaps, act as a "French drain," while the water is low; but if the freshet rises above the top of the culvert, the water in soaking through will bring down the earth just above the loose rock, and away goes the bank.

Our modern system of building embankments with dump-cars increases the danger of this; and although the contract generally provides that "all embankments shall be made in well-compacted layers of not more than — feet each," yet many might be found to which that description could not apply. Therefore, it may pay to borrow enough earth at the spot to make the embankment immediately above and around the culvert free from suspicion in this respect.

I wish I could say that "water-way" did not cost anything! But, like most other good things in this life, it has to be paid for. To offset the cost of masonry in a culvert there is a slight saving in the amount of embankment required; a saving usually equal to about one-eighth the cost of the culvert. I have made some rough calculations of the cost of culvert masonry *per square foot of water-way furnished*. Of course this varies with the height of embankment, and consequent length of culvert. It also varies with the size and character of the walls and cover-

ing; the large box culverts being cheaper (in proportion to the water-way furnished) than the smaller box, or than the next size larger of arched work. The following table gives the cost per square foot of area of water-way for some culverts from 3′ × 3′ box, up to 6½′ × 5′ arch; for three heights of embankment, 5 ft., 10 ft., and 15 ft.; and for a single track road:

COST OF WATER-WAY IN DOLLARS PER SQUARE FOOT OF CROSS-SECTION (SINGLE TRACK).

Size of culvert.	For 5-foot embankment.	For 10-foot embankment.	For 15-foot embankment.	Add for double track.
3′×3′, box	$7.50	$11.00	$14.50	$2.75
3′×4′, box...........	7.50	11.00	14.50	2.75
4′×4′, box*..........	6.50	9.50	13.00	2.50
5′×4′, box*..........	6.00	9.00	12.00	2.25
5′×4′, box*..........	6.25	9.50	12.50	2.25
5′×4′, arch..........	6.50	9.75	13.00	2.50
6½′×5′, arch.........	7.50	11.50	15.25	2.75
	$6.75	$10.25	$13.50	$2.50

Prices assumed as follows:

Culvert masonry.........................	$2.50	per cubic yard.
Arch masonry.........	5.00	" "
Earth embankment...	.25	" "

* It is only where covering stone of great length and strength abound that a box culvert of 4 feet span will be found expedient.

It will be seen that the average cost of sizes given in the above table is about $10 per square foot of water-way required. It seems as if this or a similar table offered the most rapid and convenient way of estimating for small masonry preliminary surveys, due allowance being made for the average fill on any given piece of line, as well as for the special circumstances affecting the cost of stone and labor.

Many further details might be enlarged upon, such as precautions against driftwood, fence rails, logs, etc., choking the culverts from above; the multiplication of small open culverts in side-hill work in preference to relying too much upon the ditches of the cut; but the limits of a talk like this will hardly admit of more minute discussion, and I will only say in conclusion that water either above the track, under the track, or alongside the track, is the most deadly enemy of the railroad builder, and that too much thought cannot well be given to shutting this enemy out *in advance*, so that he will never become an object of anxiety after trains are running.

[NOTE.—For discussion of this paper see the Proceedings of the Boston Society, given in subsequent pages of this number of the JOURNAL..

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

April 7, 1886:—A special meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P.M., President G. L. Vose in the chair; twenty-eight members present.

Mr. C. W. Folsom read a paper on "Railroad Wash-Outs."

Mr. A. A. Folsom, Superintendent of the Boston & Providence Railroad, was invited by the President to give his experience with wash-outs.

Mr. Folsom alluded to the freshet which occurred in 1867, which caused Stoney Brook to overflow and flood the tracks to a depth of two feet. His experience in 1874 in Alabama in time of freshet was next given. The recent freshet was next alluded to, and the wash-out at Mansfield was described. Here the track was washed out for a distance of 150 feet, a train of three sleepers and five coaches having passed over this track not more than ten minutes before the wash-out occurred. At another point a 15-foot brick arch culvert was carried away, the water rising at this point about 15 feet. The cause of the failure was attributed to defective foundation laid in quicksand. This culvert is to be replaced by a 30-foot brick arch. At this point the track was left suspended after the wash-out and was used to transport material across. A photograph was exhibited showing the track as it existed after the flood had subsided. At another point the road-bed was washed out and the track left suspended for a distance of 150 feet. At another point 2,000 feet of track was washed out. At another point the track was two feet under water and was used during the flood. From thirty to forty minutes' time was required in passing this place. The total estimated cost of repairs on the Boston & Providence Railroad was placed at $75,000.

Mr. H. Bissell, on the B. & M. R. R., had less trouble than other roads in the vicinity. Seven or eight culverts washed out. The cause was probably defective work in construction.

One cause of wash-out was that culverts were not often designed of sufficient size. Narrow culverts cause a deepening of channel and a consequent undermining of foundation. Sheeting should be driven at the ends to prevent this.

Farmers sometimes build fences across the culverts to keep cattle from passing through. This practice of fencing reduces the area of cross section. Another cause of wash-outs is that culverts become clogged by floating *débris*.

To obtain deep trenches on adjoining land, farmers have been known to dig out the channel in culverts below the bottom of foundation. This is another cause of wash-outs. Where railroad embankments are washed out for a considerable distance, the cause is due to the direction of the stream being parallel with the embankment. After once breaking through, the flood carries everything before it.

Mr. L. B. Bidwell claimed that the cost of culverts was greatly increased in large culverts because of the large stone required for covering; the material for side-walls cost less. The material in embankments around culverts should be thoroughly compacted, to prevent the water from undermining the embankment. Paving culverts with flat stone is objectionable, unless with flags broad enough to reach under the side walls. Particular cases require special treatment. Round cobbles make good paving, the round corners do not catch floating material. Wash-outs on the N. Y. & N. E. R. R. were attributed to the fact that the area of cross-section of culverts was reduced in time of freshet by the rubbish from fields and rails from fences collected and retained at the culvert.

Mr. J. W. Ellis, of the Providence & Worcester Railroad, stated that the change in course of a river as described in Mr. Folsom's paper affects the banks at the outlet of the new channel where the change is very abrupt, and requires special care in the alignment of the new channel and the protection of the river bank. A case, similar to the one mentioned by Mr. Folsom, located on the Providence & Worcester Railroad was described, and the effect stated to be exactly as described in the paper. The most serious wash-out on the Providence & Worcester Railroad was at Lonsdale. At this point one track was completely washed out for 1,200 feet; this was all done in less than 3 minutes from the time the wash-out began, and not more than 20 minutes after a train had passed over it. About 135 feet of the other track was left suspended and was used in building temporary trestle. Measurements taken on this piece of suspended track gave a camber of about 6 feet, and located the pull on the track as extending from 200 to 250 feet each way. The temporary trestle was completed in about 36 hours. The foundation of the trestle was in quicksand. This trestle settled about 5 inches. At another point where the embankment was washed out the break was stopped by using sand bags and stone. A forty-foot stone arch culvert was undermined at one abutment on the face of the arch. On the stream where this culvert was built every dam and bridge was carried away and the arch was filled with débris. Plans of this arch were exhibited, showing its condition before and after the flood.

Mr. G. R. Hardy, of the B. & A. R. R., stated that land-slides were the exception on that road, from the fact that it was built on hard foundation. The freshet of 1869 was noticed and the damage done on that road near W. Brookfield. Several bridges and culverts were washed away. Also at Wilbraham a culvert was carried away. The cost to replace this culvert was $46,000. The freshet in 1875 was alluded to, and the freshet in 1876 caused by the Worcester dam giving away.

The advantages of iron bridges over arch or box culverts was shown, attention being called to the fact that if iron bridges were used, the damage caused by flood was usually confined to the bridge without damaging the abutments. After the flood had subsided the iron work could be replaced at much less expense than an arch or box culvert.

[*Adjourned.*] H. L. EATON, Secretary.

APRIL 17, 1886 :—In the absence of the President and Vice-President, Mr. Desmond Fitz Gerald was elected Chairman. Fifty Members and three visitors present.

The records of the annual meeting and dinner, and the special meetings of March 24 and April 7, were read and approved, etc. After reading the records, Mr. D. Fitz Gerald resigned the chair in favor of Vice-President Rice.

Messrs. F. C. Coffin, G. E. Evans, G. A. Nelson and F. B. Knapp were elected Members, and eight applications for membership were read.

The following recommendations, submitted by the Government at the annual meeting, were accepted and adopted :

That a vote of thanks be extended the General Manager of the B. & A. R. R. for the use of the rooms occupied by this Society.

That a Special Committee on Library be appointed.

That the cost of book-cases in the Society's room be paid from the Permanent Fund.

That the salary of the Secretary be fixed at $100, beginning March 21, 1886.

On motion, it was Voted, That it is inexpedient to take action on the recommendation of the Government concerning the list of corresponding members.

On motion, it was Voted, That the Government be requested to prepare a form of amendment to the Constitution, to provide for the necessary changes in Articles XIV. and XV.

The Special Committee on Preservation of Timber was continued as at present constituted, with the name of H. Bissell added.

The Committee on Weights and Measures was continued as at present constituted.

The matter of appointing a Committee on National Public Works was laid on the table until the next meeting.

The Government was authorized to appoint a Committee on Excursions.

The matter of printing a record of meetings, to be distributed among Members as soon as possible after each meeting, was referred to the Government, with full powers.

Mr. Fred. Brooks submitted in writing the following addition to the By-Laws: By-Law II. The salary of the Secretary shall be one hundred dollars a year.

On motion of Mr. C. W. Folsom it was Voted, That a Committee of three or five be appointed by the President to consider and report on the expediency of adding to the number of special committees (in some such way as is done by the various western engineering societies), with a view to the preparation of papers, or to discussions and reports on various subjects, said Committee to submit any recommendations it may deem expedient.

Mr. G. W. Blodgett read a paper on the Application of Electrical Apparatus to Railroad Signals, and exhibited and described models of track and signals, illustrating his paper.

Mr. G. R. Hardy read a paper entitled Notes on the Application of Railroad Signals.

Mr. Dexter Brackett read a paper on Rain-fall Received and Collected on the Water-sheds of the Sudbury River and Cochituate and Mystic Lakes.

[*Adjourned.*] H. L. EATON, Secretary.

MAY 19, 1886:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:10 P. M., President George L. Vose in the chair. Forty-one Members and six visitors were present.

The record of the last meeting was read and approved.

Messrs. A. B. Drake, G. A. Ellis, J. W. Ellis, F. S. Hart, C. D. Jameson, B. C. Mudge, M. B. Smith, G. M. Tompson were elected Members of this Society.

Mr. Charles H. Haswell was proposed for Honorary Membership, recommended by F. Brooks, H. Manley. Mr. Arthur Winslow was proposed for membership, recommended by H. H. Carter, C. M. Wilkes.

Mr. C. W. Folsom submitted a report from the committee appointed to consider the expediency of adding to the number of special committees: That it was inexpedient at present to increase the number of committees and that the Committee be given further time to consider the subject. The Committee were given further time.

The followed proposed amendments to Articles XIV. and XV. of the Constitution were adopted by a vote of 18 to 0.

AMENDED ARTICLE XIV.

Any person duly elected shall become a Member on subscribing his name to the Constitution and paying ten dollars to the Treasurer, *and the cost of the* JOURNAL *from the date of admission to the date of the next annual meeting.*

AMENDED ARTICLE XV.

Members shall be liable for such assessments as shall be voted by the Society, except that during residence fifty miles or more from Boston, any Member whose dues have been fully paid, and who shall give written notice to the Secretary, may thereby be exempt from any assessment levied before the next annual meeting, and by the payment of *four* dollars, at or before the annual meeting, may retain his membership and be exempted from any assessment during the year fol-

lowing such annual meeting, or for any less period that his non-residence shall continue.

The additional By-Law proposed in writing at the last meeting was adopted by the following vote: Affirmative, 20; negative, 0. The By-Law as adopted is: 12. The salary of the Secretary shall be $100 a year.

On motion, it was voted, That the President be requested to appoint a Special Committee on National Public Works, this Committee to consist of three Members; the chairman of this Committee to be authorized to represent this Society at meetings called by the chairmen of similar committees of other societies; provided that no expense be entailed upon the Society without express vote authorizing the same.

Voted, That a vote of thanks be extended the management of the Fitchburg Railroad for courtesies extended and transportation furnished the Society on its excursion to the Stony Brook Dam, Cambridge Water-Works, May 19, 1886.

Prof. Wm. Ripley Nichols read a paper on the use of galvanized and some other service pipes for conveying water, and exhibited samples of galvanized pipes which had been tested by him.

Mr. Chas. D. Jameson read a paper entitled "Notes on the Panama Canal." The paper was illustrated by a large number of photographs and drawings.

[*Adjourned.*] H. L. EATON, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MAY 4, 1886:—The 224th meeting was held at 7:30 P. M., President Wright in the chair.

The minutes of the preceding meeting were read and approved.

Applications to be admitted to membership were received from:

Edward T. Blake, Assistant Engineer, Chicago, Burlington & Quincy R. R., Chicago.

Richard T. Crane, Manufacturer of Machinery, Chicago.

Albert Winfield Fiero, Inspector of Steel Rails, Joliet, Ill.

William Raab Geeting, Civil Engineer, 1,460 West Lake street, Chicago.

Rudolph Hering, Chief Engineer, Drainage and Water Supply Commission, Chicago.

Fred. L. Hill, Civil Engineer, Burlington, Iowa.

Charles B. Holmes, President and Superintendent, Chicago City Railway Company, Chicago.

William J. Hotchkiss, Assistant Engineer, City Hall, Chicago.

Alexander Edward Kastl, Civil Engineer, Drainage and Water Supply Commission, Chicago.

Alexander Kirkland, Commissioner of Buildings, City Hall, Chicago.

Michael McDermott, Civil Engineer, 2,573 Emerald avenue, Chicago.

Henry H. Porter, President, Chicago & Indiana Coal Co., Chicago.

Frederick C. Rossiter, Surveyor, 1004 Van Buren street, Chicago.

Morris Sellers, Iron Master, 514 La Salle avenue, Chicago.

William Oscar Seymour, Chief Engineer, C., W. & M. R. R. Co. and C. & G. W. R. R. Co., Chicago.

Charles James Vilim, Leveler, 101 West Eighteenth street, Chicago.

The following persons were elected Members and Associates:

Members.—John B. Allan, Manager for E. P. Allis & Co., Chicago.

Samuel R. Ballard, Civil Engineer, Burlington, Iowa.

Samuel A. Bullard, Architect and Engineer, Springfield, Ill.

Joseph Phelps Card, Wood Preserving, Chicago.

John Charles DesGranges, Construction Engineer Water-Works, Aurora, Ill.

Eric Gustaf Ericson, Assistant Engineer, Pennsylvania Co., Wooster, Ohio.

John E. Ericson, Civil Engineer, Chicago.

William A. Hammett, Manager and Mechanical Engineer for New York Steam Power Co., Chicago.

Abner C. Harding, Real Estate and Insurance, Chicago.

Gustave Bernard Hegardt, Civil Engineer, Beardstown, Ill.

Eyvind Lee Heidenreich, Construction of Grain Elevators, Chicago.

John Lundie, Assistant Engineer, City Hall, Chicago.

Augustus F. Nagle, General Western Agent for Providence Steam and Gas Pipe Co., Chicago.

John Nelson Ostrone, Assistant Engineer, Bridge Department, Chicago, Burlington & Quincy Railroad, LaGrange, Ill.

Theodore Parker, Assistant Engineer, Chicago, Burlington & Quincy Railroad, Burlington, Iowa.

Orrin W. Potter, President North Chicago Rolling Mill Co., Chicago.

Ethan Philbrick, Assistant Engineer, Chicago & Alton Railroad, Western Springs, Ill.

Henry Raeder, Architect and Engineer, Chicago.

Albert W. Sullivan, Division Superintendent, Illinois Central Railroad, Cairo, Ill.

William Bryant Throop, Roadmaster, Chicago Division, Chicago Burlington & Quincy Railroad, Aurora, Ill.

Associate.—Marvin Hughitt, Second Vice-President and General Manager, Chicago & Northwestern Railway Company, Chicago.

The Secretary stated that, in behalf of the Society, he had tendered to the Local Committee of the American Society of Mechanical Engineers for the Convention, May 25 to 29, the use of the Society's Hall as a place of meeting, an excursion to Pullman, and one to the Water-Works crib.

Mr. Palmer, for the Local Committee, extended a cordial invitation to all members of the Western Society, and their ladies, to attend the meetings and social gatherings of the Convention. It was voted that the present Reception Committee be discharged and that a Committee of Ten, the President to be one member, be appointed to represent the Society at the Convention and act with its Local Committee.

An open letter, by Mr. S. S. Greeley to Hon. R. P. Bland, urging the adoption of the Metric System, was read and discussed. A bill from the Association of Engineering Societies, amounting to $109, being the third installment of the assessment of August 31, 1885, was ordered paid.

[*Adjourned.*] L. P. MOOREHOUSE, Secretary.

Members and their ladies are earnestly invited to attend the meetings of the American Society of Mechanical Engineers, May 25 to 29, in the Methodist Church Block, and particularly the opening reception Tuesday evening, May 25, at the Grand Pacific Hotel and the excursion Thursday to Pullman, South Chicago, etc.

Tickets to the banquet Wednesday evening (price four dollars) can be obtained from the Secretary.

JUNE 1, 1886:—The 225th meeting was held at 7:30 P. M., President Wright in the chair.

The minutes of the preceding meeting were read and approved.

Applications to be admitted to membership were received from:

Sigvald Udstad, Mechanical Draftsman, C. & N. W. Ry., 315 W. Huron street, Chicago.

Alva M Van Auken, Resident Engineer, Fremont, Elkhorn & Missouri Valley R. R., Fremont, Neb.

Geo. T. Wickes, Mining Engineer, Bozeman, Mont.

The following persons were elected Members:

Edward J. Blake, Assistant Engineer, Chicago, Burlington & Quincy R. R., Chicago.

Richard T. Crane, Manufacturer of Machinery, 369 Washington boulevard, Chicago.

Albert Winfield Fiero, Inspector of Steel Rails, Joliet, Ill.

William Raab Geeting, Civil Engineer, 1,460 West Lake street, Chicago.

Rudolph Hering, Chief Engineer, Drainage and Water Supply Commission, Chicago.

Fred L. Hill, Civil Engineer, Burlington, Iowa.

Charles B. Holmes, President and Superintendent Chicago City Railway Co., Chicago.

William J. Hotchkiss, Assistant Engineer, City Hall, Chicago.

Alexander Edward Kastl, Civil Engineer, Drainage and Water Supply Commission, Chicago.

Alexander Kirkland, Commissioner of Buildings, City Hall, Chicago.

Michael McDermott, Civil Engineer, 2,573 Emerald avenue, Chicago.

Henry H. Porter, President Chicago and Indiana Coal Co., Chicago.

Frederick C. Rossiter, Surveyor, 1,004 Van Buren street, Chicago.

Morris Sellers, Iron Master, 514 La Salle avenue, Chicago.

William Oscar Seymour, Chief Engineer C., W. & M. R. R. Co., and C. & G. W. R. R. Co., 164 Dearborn street, Chicago.

Charles James Vilim, Leveler, 101 West Eighteenth street, Chicago.

The Committee on Bridges presented a report on the paper by Mr. J. F. Clarke referred to that committee.

The following query was read by the Secretary and referred to Committee on Railroads, Streets, etc.:

"What is the best pavement, or improved roadway, for a city residence street having a limited amount of travel?"

Mr. Liljencrantz read a paper on "The Stadia Rod."

Mr. Wright, Mr. Cregier in the chair, read a paper, "Organization of Surveying Party"

[*Adjourned.*] L. P. Morehouse, Secretary.

Members who desire to obtain the engraved Certificate of Membership issued by the Society are requested to communicate with the Secretary, giving full name to be inserted.

Members are earnestly requested to correspond with the Secretary, or the proper Standing Committees, volunteering papers, discussions of published papers, or queries on professional topics.

The Standing Committees are urged to provide papers, discussions, or queries, on the respective topics assigned to them.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

March 1, 1886:—The regular monthly meeting of the Society was called to order in the City Engineer's office at 8:30 p. m., President Morris in the chair; ten members present.

The minutes of the last regular meeting read and approved.

Report of the Committee on Rooms was received to the effect that the next meeting could probably be held in the rooms of the Public Library.

It was moved and carried that in case the arrangements for future meetings in the Library rooms were completed before the next meeting, the Librarian be authorized to purchase a book-case and place the books of the Society in it, in the rooms obtained.

Report of the Treasurer for 1885 was read, and the books referred to the Auditor for examination and transfer to new Treasurer.

Upon motion of the Chairman of Committee on National Public Works, the Society voted to send thirty-five dollars to the Executive Board of the National Committee in reponse to circular No. 9 from Executive Board of said Committee.

The applications of the following gentlemen for admission to the Society were received and notice given :

C. C. Wrenshall, Albert H. Hogiland, H. Fernström, Howard Thomas.

The vote accepting the resignation of Mr. Lewis was reconsidered, and upon motion it was not accepted. His application to be classed as Non-Resident Member was then read and voted as in accordance with Art. 17 of the Constitution.

By-law No. 11 was, upon ballot being taken, added to the former list of By-laws.

The Secretary was ordered to have 200 copies of the Constitution printed in pamphlet form. Also the Librarian was instructed to have the JOURNAL of the Association and the proceedings of the American Society of Civil Engineers bound.

The President then read the following list of committees as appointed for the ensuing year :

Membership : H. W. Elmer, C. F. Loweth, F. T. Hampton.

Library : Wm. H. Wood, L. W. Rundlett, W. A. Truesdell.

Railroads : C. L. Aman, N. D. Miller, H. A. Swenson, C. W. Johnson, R. E. Hilgard.

Bridges and Roofs : C. F. Loweth, C. C. Wrenshall, A. Hogiland.

Water Supply and Drainage : L. W. Rundlett, A. R. Starkey, R. Davenport, Phil. Buechner, J. B. Parkinson.

River Improvement : H. E. Stevens, J. L. Gillespie, J. H. Morrison.

Mechanical Engineering : Phil. Buechner, W. F. Newell, W. S. Morton.

Materials of Construction : W. A. Truesdell, F. Lewis, J. Grondel, Randell Hunt, A. Munster.

Streets, Roads and Pavements : S. Rockwell, F. M. Tower, W. A. Somers, O. H. Hoffman.

[*Adjourned.*] GEO. L. WILSON, Secretary.

MARCH 22, 1886:—A special meeting of the Society was called by the President to consider and discuss (Circular No. 11) the action to be taken by the Society's representative at the Convention of the Civil Engineers' Committee on National Public Works, to be held in Cleveland, March 31.

The meeting was called to order by President Morris, seven members being present, and C. C. Wrenshall, Esq., as guest of the Society. After the members present had expressed their views in regard to the proper course to be taken at the coming convention, it was moved and carried that Mr. Charles F. Loweth go to Cleveland as the representative of this Society.

[*Adjourned.*] GEO. L. WILSON, Secretary.

APRIL 5, 1886:—The regular monthly meeting of the Society was called to order at 8:30 P. M.

On account of the absence of the President and Vice-President, Mr. L. W. Rundlett was chosen chairman of the meeting.

Minutes of the last regular meeting and the special meeting of March 22 were read and approved.

The communication from Geo. T. Prince tendering his resignation was read and the resignation accepted.

On separate ballots being taken the following persons were elected to membership in this Society :

C. E. Wrenshall, Howard Thomas, H. Feinström, A. H. Hogiland.

Thatcher's calculating machine was exhibited to the Society by H. N. Elmer, and its use tested by two of the members present, the remainder checking the machine results as to accuracy and speed, somewhat to the disadvantage of the machine, as to speed, etc. It was the opinion of those present, however, that with a proper amount of practice the machine was a time and labor saving invention for many kinds of calculation.

[*Adjourned*]. GEO. L. WILSON, Secretary.

MAY 3, 1886 :—The regular monthly meeting of the Society was called to order shortly after 8 P. M., President Morris in the chair, eight Members present.

Minutes of the last regular meeting read and approved.

The report of the Delegate of the Society to the Convention of Civil Engineers in Cleveland, Mr. Chas. Loweth, was read by the Secretary, Mr. Loweth being absent, and upon vote, the report was accepted without discussion.

The application of J. A. Case, C. E., was received and notice given that ballot for membership would be taken at next regular meeting. Upon separate ballots being taken Mr. Archibald Johnson, U. S. Asst. Engr., and Col. A. J. Merrill were elected to membership in the Society.

Mr. C. L. Annan presented the subject of calculating earth-work by means of Wellington's diagrams, as practiced by the C., B. & N. Railway Co., and illustrated his remarks very clearly by a set of diagrams which he presented to the Society. After some informal discussion of the subject of earth-work calculation, a vote of thanks to Mr. Annan was passed unanimously.

[*Adjourned.*] GEO. L. WILSON, Sec'y.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. July, 1886. No. 9.

THE SEVENTH STREET IMPROVEMENT ARCHES.

BY W. A. TRUESDELL, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read October 5, 1885.]

When the Seventh street improvement was commenced in the spring of 1883, it had been decided to make the Phalen Creek crossing an earth embankment, and the work in its details was to be done on that general plan. This embankment was to be 66 feet wide on the top, the full width of the street, and 640 feet long, from bluff to bluff. The greatest depth in the valley was 86 feet below grade. The filling up of this valley would require a culvert 320 feet long for Phalen Creek and a stone arch bridge at the crossing of the St. Paul & Duluth Railroad. A description of the last structure as it was built, and a history of its construction, is the object of this paper.

The right of way of the Duluth road was 70 feet in width, and the angle of intersection with Seventh street was 63° 28′. For this reason an oblique or skew bridge would be required, with an obliquity as near to the above angle as possible. The vertical distance from the railroad track to the grade of the street above was not sufficient to span the right of way with one arch, as sewer, water pipes, etc., would have to be built eventually above the arch. After conferring with the authorities of the St. Paul & Duluth R. R. Co., it was decided to cover the 70 feet with two arches, one of 27 feet and the other 37 feet direct span, reserving about 6 feet for a centre pier. This gave track room for five tracks, two passenger tracks through the small arch, and three for freight traffic through the larger arch.

On this agreement, plans were prepared and specifications drawn up during the months of June and July, 1883, and on the 27th of August following the contract for building the whole structure was awarded to Mr. M. O'Brien, contractor, of St. Paul. Before the work had been commenced, this contract was modified by resolution of the City Council, and with Mr. O'Brien's consent, so as to include only that part of the structure up to the springing lines of the arches. The remainder of the work was to be included with the other work of the Seventh street improvement, the contract for which was soon to be let.

In designing these arches, it was an earnest endeavor to keep the cost as low as possible, and, at the same time, a substantial structure was required. It was a question of great importance at this time what method of building an oblique arch to adopt. Every known method of constructing such a bridge was duly considered. Nothing of the kind had ever been built in this western country. Very few of our masons in St. Paul had ever seen one, and no one knew anything about the stone-cutting necessary. All of them would consider it an expensive undertaking. At most it was entering on an untried field of operations.

The ribbed arch plan was first considered, and then rejected. Such a structure would have been unstable for this locality on account of the great weight of earth the arches would have to sustain. The stones of one rib could not be bonded into those of the next rib. In such arches it is often necessary to insert iron tie-rods along the crown to hold the ribs together. Nothing, probably, would have been saved in the stone-cutting.

The logarithmic method, or perhaps what had better be called the French method, is the strongest oblique arch that could be built. The joints near the ends of the arch are nearly parallel to the springing line. But the voussoirs of such an arch could never have been cut in this locality. It would have required a great number of patterns and the cost of such a work would have been beyond all consideration. This method was too expensive and impracticable to be adopted.

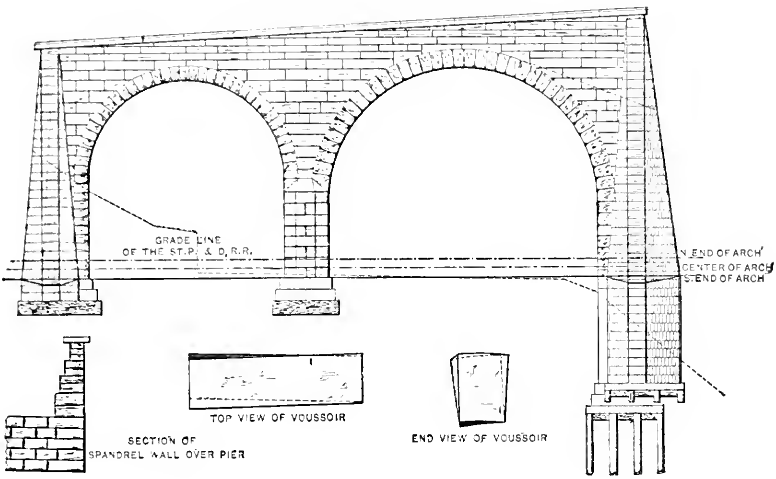
It was finally decided to adopt the helicoidal method, or the English style of an oblique arch, as it appeared to be the least difficult and expensive to construct of any of the known methods. These are quite common in England and Scotland, but very few have ever been built in this country. In this style of an oblique arch the voussoirs are laid in spiral courses, parallel with each other, and are of one size and shape throughout the whole arch except the ring stones. One set of patterns answers for all of the voussoirs, and when the stone-cutters are once taught to cut a stone no further difficulty is encountered.

The theory of the helicoidal method is this: The beds of the voussoirs, or rather the bed of any one course, is a helicoid or a warped surface, generated by a straight line which intersects the axis of the arch, and is continually at right angles with it, and which moves uniformly along that axis and at the same time revolves uniformly around it. The intersection of any one of these warped surfaces with the soffit of the arch is a curve known in mathematics as the helix, and is called in practice a coursing joint. The joints which separate the stone in a course from each other are called "heading joints," and are portions of warped helicoids. On the soffit of the arch they are at right angles to the coursing joints. The soffit of the voussoir is, therefore, a rectangle, but this is not true on the extrados of a voussoir. There the angles vary considerably from right angles. A right section of such an arch must always be circular, either semi-circular or segmental. But the arch is really elliptical, because the beds of the stones are approximately at right angles with the line of thrust, which would act parallel or nearly so to the face of the arch.

This was the method adopted for the Duluth viaduct, and both arches

were planned on that principle. These plans were for two arches, one for 27 feet and the other for 37 feet, direct span. The angles of obliquity were 63° 49′ and 63° 40′. Oblique spans were 30 feet and 1 inch, and 41 feet and 3½ inches. Each arch was to be 124 feet and 7 inches in length, both of them full centre arches, the springing line of the small one 3 feet and 4 inches above that of the larger one. The arch rings were 2 feet and 2 feet 4 inches deep. The east abutment was 7 feet and 3 inches thick at the springing line, the centre pier 6 feet, and the west abutment 6 feet and 1 inch, the total width of structure 83 feet and 4 inches. The spandrel backing was raised 10 feet above the springing line of the small arch and 13 feet and 6 inches over that of the large one. Wing walls were to be built on each end of the east and west abutments. These varied

END ELEVATION



from 47 feet to 58 feet in length and from 30 feet to 37 feet in height above the grade of the railroad. The parapet walls were to be each 96 feet long and carried up 4 feet above the crown of each arch. The height of parapet walls above track is 36 feet. The coping stone surmounting the parapet wall was laid parallel with the street grade above, which was 4 feet and 10 inches per one hundred feet. The springing lines were horizontal, but the railroad tracks descend through the arches at a grade of 2 feet per one hundred. The viaduct was subsequently built according to these plans, with slight alterations made as the work progressed.

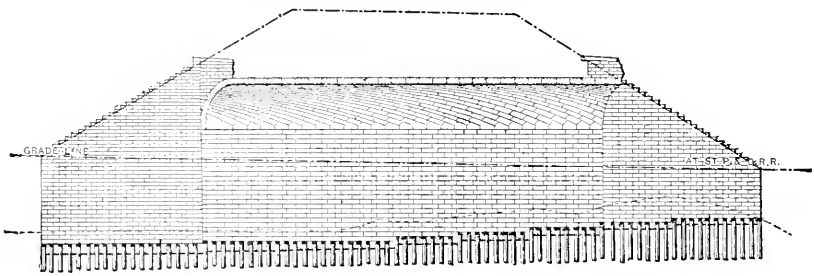
On September 6, the old Seventh street trestle was closed to travel, five bents of it removed, and the excavation for the east abutment commenced. Pile-driving for the foundation commenced September 27, and was completed on November 3. On the 10th of November, the contractor commenced laying stone, and the work continued during the winter, with interruptions at different times on account of cold weather, until the following spring, when the east abutment, with its two wing walls, was completed up to the springing line on April 20. Meanwhile, the excavation of the west abutment had been made and the laying of stone

commenced April 9, and was completed, with the two wing walls, early in May. Two railroad tracks at that time occupied the present position of the centre pier: one of them was removed, and the other thrown over near to the west abutment. The pit for the centre pier was then excavated, the sheet piling driven on each side to prevent sliding of the material, and on May 24 the masonry was commenced and completed on June 6. This finished the work under Mr. O'Brien's contract.

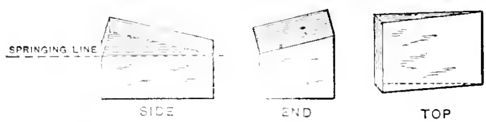
The west abutment and centre pier were built directly on earth foundations of a firm gravel and sand, with wide footing courses. Each foundation is 5 feet below the present grade of the railroad tracks at the south end, and 7½ feet at the north end. This depth was considered below the action of frost.

The foundation of the east abutment was about 18 feet below the other

LONGITUDINAL SECTION



IMPOST STONE



two, and at places was soft, and at others hard and firm, but wet for its whole length. The masonry of this abutment was built directly on piles.

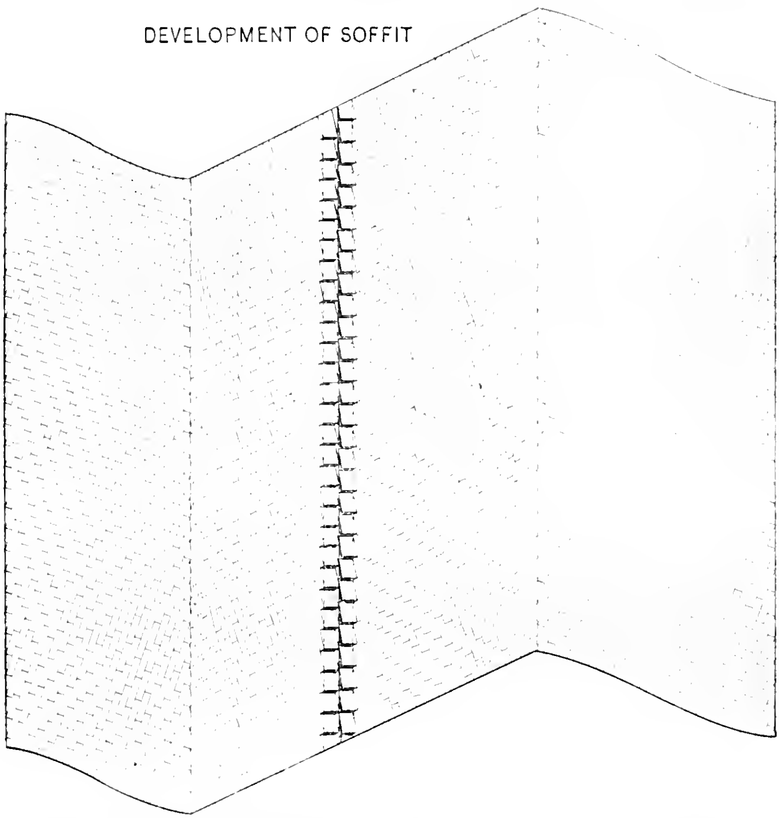
The whole work so far was built of St. Paul limestone. Louisville cement mostly was used in the mortar. The masonry was very heavy. Most of the courses were 16 inches and 18 inches thick, some of them 20 inches and 22 inches thick. No course less than 12 inches thick was allowed. The back of each abutment was built as substantial as the front, and no stone was laid in any course of less depth than the thickness of that course.

The centre pier was built after the Flemish style of masonry. Each header extends through the wall and is underlaid and overlaid by two stretchers, the width of the two stretchers being equal to the thickness of the wall. Each stretcher abuts at each end against a through header. Very little filling was allowed.

Throughout the whole work the contractor did everything in a substantial manner. The total amount of masonry in Mr. O'Brien's contract was 3,567 cubic yards, including the concrete.

Drawings of the patterns for stone-cutting had been made the previous winter, and the patterns, or most of them, made by the American Manufacturing Company, at their shops in St. Paul. These templates and bevels were 105 in number, and were made of iron, wood, zinc and paper. Those that were to be used continuously were made very solid of iron and wood. Those used once or twice only were of paper. Duplicates of these used the most were afterwards made, so that from 25 to 30 workmen could be kept at work continuously in the quarry.

The only difficulty met with in cutting the voussoirs and impost stones



was at the commencement of the work, and was in making the stonecutters understand the importance of accurate and careful work with the patterns instead of the ordinary work to which they had been accustomed. This was overcome by placing an intelligent and trustworthy foremen in charge of all stone-cutters, and from that time afterwards all work was done in a first-class manner. To Mr. Thomas Russell, the foremen in charge at Mankato, great credit is due for the successful manner in which he performed his work. Every stone was accurately tested with a set of templates and bevels made for that purpose exclusively before it was shipped to St. Paul.

The McArthur Brothers, of Chicago, under their contract for the improvement of Seventh street, continued the work from where Mr. O'Brien left it, and in July commenced laying the impost stones. After these were laid for both arches three courses of voussoirs were laid on the centre pier, two on the east side, and one on the west, and the backing put in between them in order to obtain room for two derricks, with which the whole work could be reached. The centring for the small arch was then put up and the voussoirs laid as rapidly as possible, while the centring for the large arch was placed in position. This was completed on the 12th of September, and thereafter the work of laying the voussoirs was carried on over each arch, simultaneously, until October 14, when the last one was laid in the large arch.

The spandrel backing was carried up at first with the voussoirs over each abutment and centre pier. The remainder of the stone work was then hurried to completion. The backing was completed, the wing walls and spandrel walls built, both arches were plastered over with concrete three inches thick, and the coping stone laid. A dry wall three feet thick was then built back of each spandrel wall to relieve the spandrels from the earth pressure.

The masonry of the viaduct was completed on the 25th day of November. A trestle was then built over both arches, dump cars run over from the adjacent embankment, and the Phalen Creek fill extended over the whole work. The first teams passed over the viaduct and the entire Seventh street fill, on the 18th day of December.

That part of the work built by McArthur Brothers, except the wing walls, was constructed of Mankato stone, from the Empire stone ledge of W. D. Craig & Co. Utica cement was used until cold weather, when Louisville was substituted. The arch stones were laid in mortar composed of one measure of Utica cement mixed with one of sand. There were 1,764 voussoirs and impost stones in both arches, and all of these were quarried and cut in Mr. Craig's Mankato quarry in three months' time. This fact speaks well for the capacity of that quarry. Only about one-fourth of the stone quarried was suitable for these voussoirs, the remainder was used in other parts of the work and in the Trout Brook masonry.

There is in voussoir and impost stones 1,122 cubic yards of masonry. In the whole work there are 3,474 cubic yards of Mankato stone. The spandrel backing contains 1,026 cubic yards.

Oblique arches are often built of hard burnt brick, with the ends only of cut stone, and, of course, at much less cost. It was not deemed expedient to construct the Seventh street arches in this manner, on account of the great weight of earth with which they were to be loaded. Something enduring and substantial was required. The extra cost of stone over brick was money judiciously expended.

It is probably the general opinion of the public that these arches have been an expensive undertaking. On account of the apparent difficulty of cutting the stone, the idea prevails that to build arches of this kind must necessarily require a greater outlay of expense than if they were right arches. I wish to contradict this idea. With the contractors of the Seventh street work, the stone-cutting was neither difficult nor expensive. The Seventh street improvement embraced quite a number of

different classes of work in given quantities, and the whole improvement was performed for a stated price. For this reason, the exact cost of the viaduct alone to the city is not easily obtained. Whatever information I possess on this subject is the property of the contractors and cannot be mentioned here. I wish merely to state that any excessive cost in the Seventh street arches does not exist. This probably could not be done again, but is true in this instance. The two arches have cost no more than two right arches would have done for the same locality.

During the progress of the work the traffic on the St. Paul and Duluth Railroad was not in any way obstructed. The centring was raised, all the voussoirs laid, and, in fact, the whole work constructed with trains and switch engines continually passing and repassing under the arches.

Each centre was built " cocket," as there was a track through each arch. The ribs were made entirely of two-inch plank, and were 5 feet 4 inches apart in the small arch, and 4 feet in the large one. The ribs were supported by plates 6 inches by 12 inches, extending along the springing lines, and these, in turn, supported by vertical posts 8 inches by 10 inches reaching to the footings of the masonry. The ribs were put together close at hand and raised to their position with the derricks. They were placed at right angles to the axes of the arches. There was consumed in these centres over 135,000 feet B. M. of timber. They were designed by Mr. Jas. McArthur, one of the contractors. During the progress of laying the voussoirs, not the slightest settlement in either was noticeable. The lagging was 3 inches by 6 inches, timbers 16 feet long, thoroughly spiked to the ribs and planed on the upper surface. On this lagging the coursing joints were all marked from the impost of one side over the lagging to the other impost. It would have been impossible to have laid the voussoirs without this precaution. On these lines strips one-half inch by two inches were nailed, and on these strips the coursing joints were again drawn. The faces of both arches were also drawn across the lagging. These lines were guides for the masons in bedding the stones, care being taken to make the joints always correspond with the line. The voussoirs were not laid by courses, but in horizontal rows from one end of the arch to the other, both sides brought up at the same time; when the last row of keystones was put in, it fitted to its place and was grouted with mortar made very rich with cement.

The total amount of work done under the two contracts is as follows:

Earth excavation	7,172	cub. yds.
Piling	3,487	lin. ft.
Concrete	168	cub. yds.
Masonry in east abutment	1,222	" "
Masonry in west abutment	588	" "
Masonry in centre pier	586	" "
Masonry in wing walls	1,437	" "
Masonry in arches	1,122	" "
Masonry in spandrel backing	1,026	" "
Masonry in spandrel walls	326	" "
Plastering on arches	635	sq. "

Total amount of masonry in the whole structure, 6,528 cubic yards.

There are, in the smaller arch, 62 impost stones and 754 voussiors. These voussoirs are all of the same size, except the ring stones, and are 5 feet 8½ inches in length, and 2 feet deep, and contain 14.8 cubic feet. Each one weighs 1.15 tons. The large arch has 48 impost stones and 900

voussoirs. The voussoirs are of different lengths near the springing lines, after which they are all of the same size, 4 feet 11 inches long and 2 feet 4 inches deep. Each one weighs one and a half tons. All voussoirs and impost stones are bush hammered on the soffit. The embankment over each arch is 18 feet deep. The greatest pressure on any part of the work is at the skew-backs of the large arch, where it is 170 pounds per square inch.

After the whole work was completed, the centres were allowed to aremin in place during all of the past winter until May, when both of them were struck and the timbers removed. Each rib was loosened so easily that it seemed to indicate that the arches had been to a great extent supporting themselves. This was probably due to the shrinkage of the timber during the six months that it had remained in place.

It is advocated by some, that centres should be struck as soon as the stone work over them is completed. The experience with these arches appears to prove the contrary, and that the safest plan is to keep them in place as long as possible.

ANNUAL ADDRESS.

By J. F. Holloway, President Civil Engineers' Club of Cleveland.

[Delivered March 13, 1886.]

I shall occupy the time at my disposal in attempting to say something about the "Engineer and what he has accomplished."

I find myself at the beginning embarrassed by the difficulty of giving a satisfactory definition of the term, engineer, even the name of our association is to some extent a misnomer. While its title is the "Civil Engineers' Club," its constitution gives as the object of its organization "the encouragement of social intercourse among men of practical science and the advancement of engineering in its *several* branches," and it also provides that its "members shall consist of persons who are or have been engaged as civil, mechanical or mining engineers, architects, astronomers, geologists or analytical chemists and other persons engaged in scientific pursuits." Comprehensive as is this list of persons who are eligible to its membership, it by no means includes all of the recognized branches of engineering or of engineers. If, years ago, when engineering was far less comprehensive in its scope, when it was confined within comparatively close limits, it puzzled the ablest lexicographers to clearly define its meaning, how much more difficult must it be to do so now, since the engineer has invaded so many pursuits which hitherto got on very well without him.

That there were engineers long ages ago is testified to by the ruined structures still to be seen; structures for whose formation there was need of carefully prepared plans and carefully constructed appliances. Three thousand years before the Christian era began, in that wonderland of the past, Egypt, engineers planned and built an artificial reservoir which, for vastness, has never yet been equaled. For its protection there was built a wall of masonry 40 feet high, 30 feet wide and 27 miles long; within it

were numerous gates connecting with channels through which in times of flood, the waters of the Nile were turned aside to be returned again in times of drought, through irrigating canals that made that now desert land to blossom as the rose. The first signal station of which we have any record, was a nileometer placed in the far away sources of that historic stream, to give warning of the coming flood in time to prepare for its storage. The steady, onward tread of those Roman legions which once made Rome mistress of the world was made possible by the labors of the sagacious and skillful engineers, who built for them imperishable roadways, spanned rivers with bridges which are marvels to-day, and who laid so deep and so permanent their foundations in the then far off "Isles of the Sea" that the engineer of the present, as he excavates for his railways and buildings, often reaches the embedded stone or crowning arch laid by his professional brother thousands of years ago.

The more modern engineering, as it has existed in the one hundred or so years past, has been in the main confined to that class, known as civil engineering, and which embraces the location and construction of fixed public works, such as roads, canals, bridges, aqueducts, breakwaters, dams, sewers, docks, etc.

But most wonderful changes have taken place within the last 50 years or so. The rapid progress made in arts and science, largely due to what engineers had previously accomplished, have so widened the scope of engineering that it has been necessary to add numerous other branches, and subdivisions. The impetus given to commerce, agriculture, and indeed to all industrial pursuits, by the invention or at least the improvements in the steam engine, has made a necessity for a branch of engineering, now known as mechanical engineering; and, so great is this field of engineering, so wide its range of usefulness, that it has become necessary to sub-divide it into specific branches, such as steam, hydraulic, agricultural, sanitary, gas, electrical, and other engineering; each of which has now assumed such importance as to require the especial training of engineers to master its difficulties. The wonderful improvements in the production of metals recently made, and especially of iron and steel, and their substitution for wood and stone of late years has greatly enlarged the province of the mechanical engineer. In many structures of the present, where previously only the architect, the mason and the carpenter would have been called upon, now that iron and steel, in one form or another enter so largely into their construction, the mechanical engineer and his machine appliances are of necessity called in to assist in their erection.

Michael Angelo, that prince of painters and architects, whose fame in many ways has come down to us from out the past, and whose magnificent dome of St. Peter's, which, since its completion hundreds of years ago, has challenged the admiration of the world, would have found but slight use for an engineer in his day, and little did he dream that the time would come, as it did, when the services of the mechanical engineer would be called in to save, with his bands of iron and steel, from destruction the structure he had rebuilt and of which Lord Byron speaks as, "That vast and wonderous dome, to which Diana's marvel was a cell."

In the construction of modern buildings, both for public and private

use, the services of the engineer is now most needful. If the structure is wholly of iron, it is almost his province alone to plan and construct it, and if it is to be of iron, brick and stone, his judgment is no less valuable in its plan than in its construction. The questions of heating, ventilation and drainage have of late years assumed an importance sufficient to warrant the establishment of the profession of the sanitary engineer, and the mechanical engineer, in addition to what he may have to do with the structure itself, is also called upon, to supply it with steam boilers and engines, with hydraulic or other lifts, with fans for ventilating, steam pipes for heating, and with water pipes, to which there are, in some cases, a complex system of automatic sprinklers attached to put out fires.

In addition, the electric engineer adds his plant for lighting, to eclipse or aid what previously the gas engineer had been doing, and the prospect now is, that with the introduction and use of natural gas for heating and lighting, there will grow up another branch of engineering before that substance can be safely and economically carried for long distances and be brought into common use with reasonable safety.

In naval architecture what wonderful changes a few years have wrought. The wooden walls of old England, the pride of the forefathers, the burden of sea songs, and naval dramas, are almost a dream of the past. If Britannia rules the waves now, it is inside of an iron hull, filled with boilers, engines, steam and water pipes, and wheels without number; and it is the pressure gauge of the engine room, to which the master must look for his speed, instead as of old to the well-filled sails, or the fly at the main truck. Manning the yards and unfurling the sails is now changed to wheeling the coal from out the bunkers, and crowding the furnaces; and the shrill cry of the boatswain has been hushed by the engine-room bells, or the louder shriek of the steam whistle. Every movement of the ship, from the weighing of the anchor, the swaying of the rudder, to the handling of the guns, is now done by steam, and is dependent upon the engineer and his contrivances. But not alone are naval battles fought by steam, and steam machinery, and by swift and powerful ironclads which float upon the water, but a new and still more destructive warfare is now being introduced, in which submerged torpedo boats filled with ingenious mechanism and powerful compositions sunken out of sight, by one blow under the armored side, may open a rent that will soon sink the largest ship. But, not content with usurping the sea, the engineer seems to be as well the coming man in military maneuvers on land.

You will remember how, not long since, a Yankee with his patent machine-gun, in search of customers, wandered up into the region of our Canadian friends, who at the time were busily engaged in putting down a rebellion among the Indians and half-breeds. Happening to arrive on the eve of an engagement, and anxious to show what a mechanical soldier could do, he ran his multiple machine-gun far in advance of the army, where, by himself, he unlimbered his gun, filled up his cartridge-hopper, adjusted his crank and turned it with such unceasing speed and with such effect that he actually drove the enemy away and won the battle before the regular soldiers could be brought into action.

I have no need to refer at length to what the engineer has accomplished as a common carrier. The great changes that have taken place of late years, in the transportation of merchandise, food, and the innumerable products of industry, and especially in the increased rapidity, and comfort of traveling, would have been deemed most marvelous but for the fact, that so many other equally wonderful changes have been accomplished in other directions. The "White Hart Inn" and "Tony Weller" went out with the stage coach, and the prancing bays; the horn which in earlier days awoke the echoes through many a thrifty country town, and smiling valley, has given place to the scream of the steam whistle, and along by the peaceful river, and by the meadows where once the Concord coach swung lazily in its leathern thoroughbraces, the locomotive, with its rattle and roar, sweeps around the curve, and at night its flashing light for a moment gleams out upon the darkness, as with breath of flame and cloud of smoke it rushes onward, trailing its long line of gilded palace cars behind it. On the rivers the slowly drifting raft and barges have passed on and out of sight, never to return again; and the steamer with its fleet of tow-boats now crowd the channels and wind about the hidden bars. On these lakes, where but a few years ago white-winged messengers of commerce, with snowy sails at early morn loomed up all along the shore, and whose taper spars stood out clear and fair along the horizon at sunset's hour, all are slowly but surely dropping out of sight; and now the dingy steamer, with its boilers and engines, not only moves unchecked along the storm-tossed furrows of the main, but behind it and amid its sooty trail, other sparless barges sullenly follow at the end of a tow line.

Agriculture, that oldest of occupations, whose beginning was made just outside the gates of Paradise, has in these later years been invaded by the engineer as well. For a long time he was content to substitute for the bent root of a tree, a plow of iron, but later on he devised all kinds of mechanical appliances, not only for tilling the soil but for planting and securing the crops. To-day, the steam gang plow turns up in broad deep furrows, soil which for a thousand years had been dug by hand or scratched over with some rude wooden tool and the prepared ground is now sown by a seed drill, on which the mounted granger of to-day rides at his ease; while vibrating knives, moved by wheels and cranks of endless variety and puzzling ingenuity, creep into the harvest field, and with tireless speed make the golden grain to bow before the genius of the engineer, as if swept by the blast of the storm king.

Now steam-driven threshers cull out the ripened grain, while steam elevators hoist it into bins, and steam cars or boats convey it to its destination. There was a time of which it was said, "there were two women grinding at a mill, and one was taken and the other left," but long since the engineer came along and the other was taken also. No longer the muzzled ox treads the corn, or the patient and toiling woman grinds it. The engineer, with his whirling mills, came to her rescue, and, thanks to his skill and his industry, woman has been lifted into a higher, nobler sphere of usefulness, with time and opportunity given her to train and teach her boys to follow along the line of progress, to take up the task which older hands will lay down, and bear it onward until the millennium shall come.

But it is when you enter the field of industrial arts that you are most amazed at what the engineer has accomplished. Compare for a moment the Hindoo of to-day who, as a thousand years ago, sits on the ground distaff in hand, spinning his little thread of flax, or cotton, while his neighbor at his rude loom weaves it with patient care, but at the slowest pace. Compare this picture—I will not say with a city of whirling spindles and throbbing looms—but compare it with a single mill or corporation in one of our Eastern States. Not long since I had the pleasure of going through a very extensive cotton mill, and while I do not intend to go into an elaborate statement concerning its capacity or business, I will say that its floor surface exceeded by two acres the entire surface of Boston Common. Its yearly consumption of coal was 25,000 tons, although more than one-half of its work was done by water power; while its gas bills were $35,000, and its combined yearly product was one million yards of fabrics, being enough to go two and one quarter times around this globe. To make this there was spun enough thread to reach from the earth to the sun and back, and have enough over to tie one end on the moon; and all this in one single corporation, and in a single line of industry.

Think for a moment as to what would be the size of a river that could contain within its banks all the water that is being raised by the pumping machinery of this country alone. Think of the fiery stream that would flow, were the combined output of all the blast furnaces turned into one channel. The tales told us of Vesuvius' terrible outbreaks, which desolated countries and buried cities, would be but a purling brook beside the outpouring of iron, cinder and flame could all the furnaces of the land be combined in one grand avalanche of fire.

But it is hopeless to attempt any summary of what the steam engine, with all its added trains of wheels and shafts, and spindles, and all the unnumbered machines attached to it, is now accomplishing. If I were asked to point out in what particular direction the influence of the engineer has been of the most importance and value to the world, I would reply that it has been in his labors and success in cheapening and increasing the production of the metals, of which iron, in its various forms, is undoubtedly king. When an ancient monarch was displaying his gold, a sage said: "but if another comes with more iron than you have, he will be the master of all this gold."

While iron was rare the world moved slowly, the revolving centuries saw little progress either in the condition of the inhabitants thereof, or in the face of nature: but with the increase of iron began the world's improvements, and nothing during the fifty years just past contributed so much to the rapid increase of knowledge and the improvement in the condition of mankind as the discoveries made in the production, and use of iron and steel.

It is in the harmonious working together of engineers of the various professions, that the car of progress is made to move forward in spite of all that ignorance or superstition has done to block its wheels. As I have said, the architect can no longer ignore the engineer; that his structures shall be enduring, healthful and comfortable, he must enlist his aid; and while the engineer alone might build both solid and endur-

ing he needs the aid of the architect to mold his more severe lines into curves of grace and beauty, perchance to tone, and soften by the aid of judicious ornamentation and coloring, his otherwise blank and barren walls. It is the civil engineer who, with trained skill, peers into the unbroken forest, seeking amid its tangled wilds a pathway for commerce. With transit, chain and level he measures as he goes, applying now and then his well-studied formulæ in order the better to decide which way will best suit the means at his disposal, as well as the future adaptation for economic traffic. At the river's bank he measures for the iron bridge; at the head of the divide he plans for a rock cut tunnel, and, after the mechanical engineer with his machine tools has furnished the material, and formed it into bridges, has with steam, compressed air to work the machine drills that are to bore through the rocky barrier; has with blast furnaces, Bessemer converters, blooming and rail mill trains brought forth the steel rails for the roadway, then is all made ready for the advent of that noblest of all engineering achievements—the locomotive. At once a monster of iron, brass and steel, a steed sleek and handsome in all its burnished accoutrements, gentle and obedient under the hands of its master, but when roused to its uttermost speed an ungovernable fiend, which often drags to a death from which no human power can save, hundreds of lives.

There were, it is true, many wonderful things accomplished long before machinery became so important a factor in the world's progress as it now is. Thousands of years ago a canal was dug connecting the Red Sea and the Nile, where, doubtless every cubic foot of the material moved was carried on the heads of slaves. But not so of the modern Suez Canal, built by that renowned engineer, De Lesseps. Along the fever-breeding marshes and through the bitter water lakes of that once glorious, but now desolate land, immense floating steam dredges scooped up the sacred soil of the Pharaohs by tons and dumped it far beyond its banks. Steam pumps through long lines of iron pipes brought the fresh water of the Nile to every camp, and thus, by the use of modern steam and other machinery there was constructed, in a much shorter time and by a much less number of men, one of the greatest and most important canals of the world; and, it is safe to say, if a gateway shall ever be opened across our continent, through which the commerce of the Atlantic shall float into the waters of the Pacific, it is to the use of the mechanical appliances of the engineer we must look for its accomplishment.

I speak of these things only to show to what an extent the world is indebted to the labors of the engineer; and, I hesitate not to say, there is no other profession to which you can point which has done so much for human progress. You may speak of learning, and of learned men, and it is true, that the wisdom of the past reflects in some sort upon the present, but how ephemeral was all their accumulated knowledge. Three thousand years ago, in one grand library, in one of Afric's greatest cities, was gathered the wisdom of all the ages; but, alas! the torch in the hand of a single person, in a short, brief time, swept all that wealth of wisdom into oblivion; but, thousands of years afterward, a poor unlearned man patiently carved in blocks of wood the letters of the alphabet, which, grouped together and placed under a press, gave im-

pressions that could be copied innumerable times, and thus did for the world a service of far more value than did the monarch who had gathered together the once famous library of Alexandria. Those were palmy days when in the academic groves of Greece and in Athenian temples the youth were taught by philosophers and sages. Those were days of elegance and ease, when from out the marble quarries of that once famous land, where from under the skillful hand of renowned sculptors there was created the gods and goddesses which filled the magnificent temples and palaces of that land, which, unearthed to-day from out their ruins, challenge the admiration of all the world. But ancient Greece, with all its learning, all its profound philosophy, its noble architecture, its beauty of sculpture and of decorations, sunk from out the world and left only its ruins to posterity; and who will not say that the discovery of portable type, coupled with the inventions and improvements of our own engineers, in the rapid steam rotated press which now sends its leaves into all lands, eclipses by far any previous achievement made by man.

All along the ages there have arisen kings, warriors and statesmen, who in one way or another for the time being were the leading spirits of their day; and who held the destinies of nations in their hands; but how completely has the influence they once exerted faded out; their names and deeds are alike buried under the dust of the past, scarce remembered, or forgotten forever. It is true they made and unmade kingdoms, they reconstructed the maps of their times, by pushing boundary lines here and there as conquest or disaster followed their armies; but what, after all, did they accomplish for the world's progress, or the real benefit of their race.

Hannibal and Napoleon, with their armies, crossed the Alps. Their pathway amid the clouds was strewn with thousands upon thousands of those who fell by the way, and of the proud armies who at their base began the ascent comparatively few reached the sunny plains beyond. They had indeed crossed the Alps, but behind them their snowy peaks defiantly still touched the clouds, unharmed, unconquered. Long years after these warrior chieftains had crumbled into dust, another, mightier than Hannibal, or Napoleon, came to the foot of these rock-barred barriers, which for ages past had defiantly said alike to king and peasant, "Pass me only at your peril." With no long retinue of soldiers, no vast caravan of horses, and elephants, and bleating herds, no waving banners, no blare of trumpets, or cry of herald, came the conqueror of our day.

Watching the weary traveler and burdened beast climbing with patient toil along the narrow pathways and about the storm-beaten crags, half hidden in the clouds above him, and beside yawning gulfs no eye could fathom, he bethought him of a better way. Seeing near by a dashing torrent which for ages had, unconfined, tossed high in air its flakes of foam, he knew he had in that a giant force to do his bidding; so, curbing its wild spirit, he bade it turn his wheels, swing his cranks, move to and fro his ponderous plungers and pistons. He made swinging valves at each opening stroke to gather in that wildest, freest and most untamable of all elements, one of which it was said, long, long ago, "It bloweth where it listeth"—the air—and, driving it before him through

long and tortuous passages, he made it to knock with arm of steel upon the portals of the hitherto impenetrable walls. You know the rest. With highest skill and unceasing industry he bade the spirits of the air and water alike to do his bidding, guiding them to the right and to the left, up and down, as occasion required, and from either side, through months and years, until at last the hitherto defiant walls were broken down, and the eager men leaped through the rent mountain not to engage in deadly conflict or savage hate, but to clasp each other in bonds of equality and fraternity. Through this open portal to-day, on roadway of steel, luxurious carriages glide swiftly and securely, filled with the inhabitants of all lands, on errands of pleasure, peace and good-will: while other vans loaded with the product of the field and vine, the spindle and the loom alike, pass from Italy's sunny plains to the north land of snow and ice for barter or exchange.

Need I ask who conquered the Alps—the soldier or the engineer? Need I ask whose triumph has contributed most to the welfare of the world—the general's who went over the Alps, or the engineer's who went through them?

Let Mont Cenis and St. Gothard answer.

The time at my disposal is past, and as other and more enjoyable exercises await you, I will not further pursue a subject about which there still remains so much to be said. Permit me to add in conclusion, that it is proper and fitting that in a city whose rapid increase in population and business is due so largely to the fact that the invention, industry and skill of the engineer brought to its once quiet streets the now numerous converging lines of railways; to its docks fleets of large and powerful steamers laden with the product of the soil, the forest and the mine; to its suburbs, so recently the quiet home of the tiller of the soil, immense furnaces, whose flames light up the midnight sky: vast manufactories filled with all kinds of powerful and ingenious mechanism, which convert with rapidity and cheapness, the crude materials of the earth into forms of usefulness and beauty; engineers who have spanned its valleys with massive and enduring viaducts, its rivers with numerous swinging bridges, with immense engines whose moving plungers and beating valves transfer from Erie's placid bosom to ten thousand gushing openings, the life-giving water; engines beneath whose fierce blast the obdurate ore is made to yield the metal hidden therein for uncounted ages; engines from out whose revolving rolls there flows the rails of steel for roadways, over which unborn States will in the future send their garnered grains; fiery rods, which, drawn into wires, lace the air with lines of steel, over which, by the aid of lightning, we send alike messages to all the world, or by word of mouth converse with towns far away; or, with coronets of beauty and brilliancy hung out in the sky, light up the night by the aid of solar energy stored ages ago in the deep caverns of the earth, there to await the magic touch of the engineer, whose province it was to bring it forth to illuminate the world and benefit mankind—it is fitting, I say, that engineers who, in so many ways, have aided in bringing about these results should meet together here for congratulation and social enjoyment, and let it be our high-

est ambition so to conduct ourselves in every position we may occupy in life, that we shall ever honor our calling, and shall assist in raising it in the estimation of all, to that high position of honor and usefulness to which, by reason of what it has done and is doing for the world and humanity, it is so justly entitled.

ORGANIZATION OF A SURVEYING PARTY.

By Augustine W. Wright, Member of the Western Society of Engineers.

[Read June 1, 1886.]

I was asked the question, "What is the best number to constitute a party upon a railroad survey?" In order to elicit discussion and get the views of our members, I would say that a party who surveyed twenty-four miles in one day of the U. P. Railway, Eastern Division (now Kansas Pacific Division of the U. P.) was composed as follows:

1st. Engineer, who was mounted on horseback and proceeded in advance of the party, accompanied by a man with a shovel, who threw up little mounds of sod to indicate the line.

2d. Front flagman, mounted on horseback, who kept in advance of the transit party, going from mound to mound and putting in a stake upon which he gave the transit-man a fore-sight.

3d. Two front chainmen, who relieved each other at intervals of one mile, the one who was not dragging the chain riding in a wagon carrying stakes.

4th. Rear chainman.

5th. Axman to drive stakes.

6th. Man to number stakes.

7th. Transit-man with wagon to move quickly from point to point.

8th. Topographer.

The level party consisted of two levellers and two rodmen, accompanied by a wagon to move them forward quickly. The line of levels, for instance, started from a bench-mark. The wagon in the mean time had gone forward, containing the other leveler and his rodman. The latter was dropped one mile from the starting-point and the leveller taken 500 feet or more ahead. The rodman drove a peg in front of the mile stake, and had his rod ready on it by the time that the level was set up. The wagon then retraced its course about a thousand feet, and awaited the arrival of the first level party. So soon as the last rodman had reached and held his rod upon the peg put in by the other rodman, this party proceeded ahead one mile, and so on.

These twenty-four miles were surveyed Sunday, August 4, 1867, and this was the "biggest" day's work upon the survey to the Pacific. We frequently surveyed 16 miles with one set of men, but leveller, rodman, two flagmen and transit-man were provided with saddle animals. The country was prairie and utterly destitute of timber, and comparatively level.

TESTS OF POWER OF LOCOMOTIVES.

By C. H. Hudson, Member of the Western Society of Engineers.

[Read March 2, 1886.]

At the time of making the experiments to determine the frictional resistance of railway trains described in a recent paper, the writer also made some experiments to determine the power of a locomotive and also to ascertain what proportion of its weight upon the drivers could, under favorable circumstances, be utilized. Still later, in testing some newly arrived engines, he made other experiments bearing upon the same question. These are the subject of this paper.

The engine and cars in the first series of these experiments were the same described in a former paper (Journal of the Association of Engineering Societies, December, 1885), the same weights being used. As the description gives the weights in gross, it is not necessary to give the details again. It is proper, however, to say that the engine had cylinders 17 × 24 and 58-inch wheel.

Experiment 7.—Trial of power of engine on curve, being seven hundred feet of two degree curve and seven hundred feet of three degree, and upon a grade averaging .91 per 100 feet, or 48.05 feet per mile. Track only in fair condition.

(A).—Engine 47, weight, 58 tons; cars, 1 to 30: weight, 726.2 tons; total, 784.2 tons. Could not start them.

(B).—Engine 47, weight, 58 tons; cars, 6 to 30 = 25; weight, 605.4 tons; total, 663.4 tons. Started them a car length; 133 lbs. steam; no sand used.

(C).—Engine 47, weight, 58 tons; cars, 9 to 30 = 22; weight, 532.6 tons; total, 590.6 tons. 130 lbs. steam; started easily.

(D).—Engine 47, weight, 58 tons; cars, 7 to 30 = 24; weight, 581.3 tons; total, 639.3 tons. Moved off slowly.

(E).—Engine 47, weight, 58 tons; cars, 6 to 30 = 25; weight, 605.4 tons; total, 663.4 tons. 128 lbs. steam; moved them 60 feet.

Experiment 23.—Trial of power of engine on 2° 30′ curve to right; grade from a point 100 feet ahead of engine was as follows:

1.27 per 100 feet, elevation	.021	1.20 per 100 feet, elevation	.027
1.17 " " " "	.028	1.15 " " " "	.023
1.12 " " " "	.025	1.10 " " " "	.025
.95 " " " "	.030	1.14 " " " "	.024
1.09 " " " "	.023		

giving an average of + 1.13 per hundred feet from rear end of train to a point 100 feet ahead of engine. Track steel, in fair condition, ballasted with fine sand or gravel. Gauge open three-eighths to five-eighths of an inch.

(A).—Engine 63, 60 tons; cars, 16 to 30 and 11 to 15 = 20; 486.1 tons; total, 546.1 tons. 130 pounds steam; moved off, two or three miles per hour.

(B).—Engine 63, 60 tons; cars, 16 to 30 and 10 to 15 = 21; 508.55 tons; total, 568.55 tons. Started them all right.

(C).—Engine 63, 60 tons; cars, 16 to 30 and 9 to 15 = 22; 532.55 tons; total, 592.55 tons. Moved them 100 feet.

(D).—Same number, back to old place. Started again and took them

200 feet. Then took slack, as they stood, and took them off, but slowly.

For 200 feet from place where grade is given it eases up a little, and then is again 1.10 per 100 feet. This train, 592.55 tons, was started on the 1.13 grade (59.66 feet per mile), with 130 pounds steam, no sand used.

Experiment 24.—Engine 63 then took twenty-five cars over grades about as follows:

1,100 feet, slightly down or level. 1,100 feet + .818 = 43.19 per mile; 600 feet of + 1.00 = 52.8 per mile; 1,100 feet of + .714 = 37.7 per mile. 300 level; 1,000 feet + .9 = 47.52 per mile; with 110 to 120 pounds of steam, doing it easily, not at any time making less than 50 revolutions per minute.

Engine 63, weight, 60 tons; cars, 16 to 30 and 6 to 15 = 25; 602.85 tons; total, 662.85 tons.

Experiment 25.—The same train as in 24 was taken to the grade and curve upon which experiment 23 was tried, making 140 revolutions and 140 lbs. steam. At end of curve was making 115 revolutions; at the commencement of a 3° curve the other way (a short tangent between), 120 revolutions were made and at the end, 95; steam, 115.

At commencement of next curve (6 degrees, 52.8 grade); 48 revolutions was made. Continued on same grade and curve till stopped. Steam, 130.

Experiment 26.—On tangent; same hill; grades as follows from point where tail of train stood:

100 feet	+ 1.06	100 feet	+ .72
" "	+ 1.09	" "	+ .96
" "	+ 1.25	" "	+ 1.09
" "	+ .96	" "	+ 1.21
" "	+ .82	" "	+ .98*
" "	+ .91	" "	+ 1.13*
" "	+ .90		
" "	+ .91	Average	+ .952

Track steel, ballasted with sand, and in good shape.

(A).—Engine 63, 60 tons; cars, 16 to 30 and 9 to 15 (incl.), 532.55 tons; total, 592.55 tons. Started them easily with 131 to 135 lbs. steam; light wind in front and on right hand side.

(B).—Engine 63, 60 tons; cars, 16 to 30 and 7 to 15 = 24, 581.25 tons; total, 641.25 tons. Same place; 130 to 135 lbs. steam; took them off readily.

(C).—Engine 83, 60 tons; cars, 16 to 30 and 6 to 15 = 25, 606.45 tons; total, 666.45 tons. Took them easily.

(D).—Engine 63, 60 tons; cars, 16 to 30 and 5 to 15 = 26, 630.65 tons; total, 695.65 tons. Took them off slowly; steam, 130 to 133; no sand.

(E).—Engine 63, 60 tons; cars, 16 to 30 and 4 to 15 = 27, 656 tons; total, 716 tons. Took them off slowly, 150 feet, and steam at 135 at stop.

(F).—Engine 63, 60 tons; cars, 16 to 30 and 3 to 15 = 28, 675.85 tons; total, 735.85 tons. 130 lbs. steam; took them off slowly.

(G).—Engine 63, 60 tons; cars 1 to 30 (inc.), 723.65 tons; total, 783.65 tons. 131 to 135 lbs. steam; started them 30 or 40 feet; tried a second time and took them 60 feet; steam, 130 to 135.

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* On 6 degree curve to left.

(II).—Engine 63, 60 tons; cars, 16 to 30 and 2 to 15 = 29, 699.80 tons; total, 759.80 tons. Steam, 133 to 135; took them 100 feet.

(I).—Engine 63, 60 tons; cars, 16 to 30 and 3 to 15 = 28 675.85 tons; total, 735.85 tons. Steam, 130 lbs.: took them fifteen car-lengths and until engine was 200 feet upon the six-degree curve; no sand, wheels did not slip; moved them at rate of two or three miles per hour.

Now, the power of engine 63, estimated by the usual formula, would be as follows:

$$\frac{17 \times 17 \times 24}{58} \times \text{steam pressure in cylinder} = 119.59 \times \text{pressure in cylinder.}$$

The average grade was .952 = 50.27 feet per mile.

The resistance due gravity would be .952 × 2,000 = 19.04 lbs. per ton; resistances due other causes (exps. 8 to 22), 4.40 lbs. per ton; total, 23.44 lbs. per ton.

In the last case the weight moved was 735.85 tons, which at 23.44 lbs. gives a force of 17,616 lbs., required to move it up that grade.

As 119.59 × cylinder pressure = force (power of engine), then force = cylinder pressure ÷ 119.59.

As force in this case is 17,616, we have:

$$\frac{17.616}{119.59} = \text{cylinder pressure} = 144 \text{ lbs.}$$

But as the steam pressure in the boiler is but 130 lbs., it could not have been 144 in the cylinder. It might possibly have been 125 lbs. At that figure we would have a theoretical force of 119.59 × 125 = 14,949 lbs. Now, the actual resistance was 17,616 lbs., or more than the theoretical power, 2,667 lbs., or 18 per cent above it.

There can be no doubt as to the effect of gravity, viz.: 19.04 lbs. per ton; this, for 735.85 tons, will give 14,010 lbs., which would leave for other resistances, assuming the force of engine to be at 125 lbs. in cylinders, 14,949 lbs.; this would leave but 939 lbs. for all other resistances, or, per ton moved, 1.27 lbs.

Our other experiments prove that this cannot be correct; we must, therefore, conclude that the formula for estimating the power is not correct. If we now discard the weight of the engine and use only the weight of the train, we have moved 679.85 tons, which at 23.44 pounds resistance per ton, gives 15,936 pounds as the force required to move it. If we now assume that at that slow speed the cylinder pressure was equal to that in the boiler (hardly probable) we will have the power of the engine, 119.55×130=15.547 pounds, pretty nearly equal to the estimated force required to move the load aside from the engine. You will note that the force required to move the load, including the engine, is 43.5 per cent. of the weight on the drivers, comparing favorably with the experiments upon the Erie road many years ago, when one-third of such weight was utilized. In ordinary practice, however, but one-fifth is calculated upon as available.

Recently, for the purpose of testing a new engine of the Consolidation pattern, just received by the East Tennessee, Virginia & Georgia Railroad, we weighed a train of thirty loads, caboose and private coach, and took it with the engine to a heavy grade about a mile long, averaging

sixty-seven and one-tenth feet per mile. The grade was not even, but undulating; some being more and some less than the average. In one place, one hundred feet were at the rate of ninety-eight feet; another spot of two hundred feet at the rate of ninety-one, and, of course, to match it, other spots were less than the average. The rail was steel, fairly ballasted and surfaced only; not in first-class line. Before reaching the grade, there were about sixteen hundred feet of level; mostly on a three-degree curve to right, which curve continued eight hundred feet up the grade. Then followed sixteen hundred feet of tangent; six hundred feet of six degree curve to left; one hundred feet of ten degree to left, and nine hundred feet of six degree to left, followed by four hundred feet of tangent and five hundred feet of four degree curve to right, when the summit was reached. At the end of these curves, the section men had (as is frequently done) pushed the tangent into the curve and sharpened the curve for the first hundred feet or so. This is not taken into account. The ten degree curve was on the little spot of sharpest grade. The day was warm and dry and circumstances favorable. The weight of train was as follows:

Engine, 109,000 pounds; tender, 55,000 pounds; thirty-two cars, 1,453,160 pounds: total, 1,617,160 pounds.

The engine stood at start at water tank about fifteen hundred feet from foot of grade, and when grade was reached was making one hundred and twenty revolutions or about eighteen miles per hour. It should be said that the engine had cylinders, twenty by twenty-four inches: diameter of drivers, 59 inches: weight on drivers, 97,000 pounds. When the spot of ten degree curve was struck, it was running fifty revolutions, or about seven miles. At a point thirty-seven hundred feet from the grade, the engine came to a stand, unable to take train through, It was then backed down and two cars set off, weighing 123,500 lbs., leaving weights as follows:

Engine, 109,000 pounds: tender, 55,000 pounds: train, 1,329,660 pounds; total, 1,493,660 pounds.

This time the engine started from the same place as before, struck the grade making 150 revolutions, or 22.3 miles per hour, and in seven minutes turned the summit, making thirty revolutions, or 4.5 miles per hour. The engine averaged 145 pounds steam, was worked most of the way in the second notch from bottom, or at about an eighteen inch cut-off, the last 1,200 feet being in lowest notch, or what was called full stroke (22-inch cut-off). Very little sand was used; engine did not slip any.

While the grade was undulating, it seemed fair to take the average—which has been stated, 67.1 feet per mile, or 1.27 per cent.—giving a resistence due gravity, per ton of $.0127 \times 3000 = 25.4$ pounds.

Experiments already given show that the frictional resistance is not far from five pounds per ton. In view of the fact that the wheels of the train were too wide (as hereafter explained) we think that that is not too great, and possibly may be too small. We will assume that, however. No special pains were taken to fix the bearings; a lot of cars that happened to be in transit being taken. Assumed frictional resistance per ton, 5 pounds. We will assume the resistance due curvature to be .05 per cent. per degree. Authorities differ in this and some go as low as .03 per cent.

The writer's observations have been that in equating grades, where he used .05 per cent. per degree, and widened the gauge, an engine that would move its train steadily on a given tangent grade, would, on reaching a curve with grade equated at .05 per cent., "pick up" a little in speed; showing that the equation was a trifle above the necessities. This has been the experience of others. On the road where this experiment was tried, however, the gauge was not open at the curves—as it should have been—and, added to that, the wheels of many of the cars in the train were wide: only scant three-eighths of an inch clearance between the wheel and the rail; while the clearance should be three-fourths of an inch. In view of this it seemed that the estimate of .05 per cent. per degree was not too much. For six degree curve, this would be .30 per cent.

Or, per ton, .0030 × 2000.................................... =	6.00 lbs.
This gives a total resistance to be overcome of (per ton)...............	36.40 lbs.
Weight of engine and train being 747 tons; 747 × 36.4........... =	27,191 lbs.
But about 100 feet of the train will be on a ten-degree curve, where the resistance per degree is .05, or, for the ten degrees, .50 per cent.: the estimated resistance on a six-degree curve was .30 per cent.: here is an excess of .20 per cent., or, per ton, 4 lbs. Now, three cars are all of the train on this curve, and we have 69 tons, which gives 69 × 4.................................... =	276 lbs.
Making a total resistance to overcome of..................................	27,467 lbs.

You will note that here we develop a tractive force of 28.2 per cent. of the weight on drivers; not so great as in other cases, but much over ordinary practice.

The theoretical power of the engine would be as follows:

$$\frac{20 \times 20 \times 24}{50} \times \text{cylinder pressure} = 192 \times 130 \text{ (assumed)} \ldots = 24{,}960 \text{ pounds.}$$

The estimated resistance per ton, is:

Gravity..	25.4	"
Frictional..	5.	"
Six degree curve	6.	"
One-tenth of train will be on a ten degree curve; and we can add to this, one-tenth of the excess over six deg. or, one-tenth × 4...	.4	"
Total..	36.8 pounds.	

Divide the theoretical power 24,960 by this resistance 36.8, and we have:

$24{,}960 \div 36.8 = 678$ tons................................ = 1,356,000 pounds.

being the theoretical amount the engine would move up this grade, or about 137,000 pounds less than the actual amount moved. As in the former cases the actual work exceeds the theoretical by about the weight of the engine and tender.

Our estimate is based on an average pressure of 130 pounds in the cylinder, after a study of a "constructed" diagram of the probable pressure, assuming that when the vaive was open we had 135 pounds, or within ten pounds of boiler pressure. We cut off at twenty-two inches (called full stroke) and a trifle later the exhaust opens. The loss here and the back pressure would reduce the average pressure at least five pounds, and probably more.

The next day a train was made up of twenty-four cars freight, caboose and coach, weighing 1,048,100 pounds. Engine and tender, as before, 164,000 pounds. Total, 1,212,100 pounds.

The day was a bad one, a fine drizzling rain, so that the rail was so greasy as possible to be; the rail could hardly have been worse.

A run of one hundred and thirty-one miles was made over an undulating road, with 68 foot grades and 6 and 8 degrees curves, some long and some short: in 9 hours and ten minutes, or an average of 14.4 miles per hour, taking no account of the stops in meeting trains. The object was to see the working of the engine on the road in its every-day work and under the worst circumstances. Fortunately the rail was as bad as we could wish, and yet the engine took the lead easily and at a speed above the usual and desired speed of freight trains. Probably in no case did the pressure in cylinder exceed 100 pounds per inch, as a good speed was kept up. At these figures we would have developed a power of $192 \times 100 = 19{,}200$ pounds: dividing by resistance, say 35 pounds and we have the result, as before, 548 tons = 1,096,000 pounds; or again, not far from the weight of the train without the engine. The trouble contended with this time was the liability of the wheels to slip. Our test satisfied us that our estimate of the every-day capacity of the engines was correct, and that they would take 1,000,000 pounds besides their own weight over this part of road, with ease and at a good speed. They have since been doing it, taking one million to one million one hundred thousand pounds, at twelve to fourteen miles per hour, without the least trouble.

KNOXVILLE, Tenn., Nov. 20, 1885.

THE METRE, AS APPLIED TO LAND SURVEYING.

BY J. D. VARNEY, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read May 11, 1886.]

Let us understand each other at once. This paper discusses the metre with reference to land surveying only, and its statements are to be taken as applying only within these narrow limits, unless they expressly include more. Whether they would be true applied more broadly I neither assert nor deny.

The metric system is undesirable. It will be impossible to secure its general adoption, therefore efforts to that end are a waste of energy, and a waste of energy is to take so much from human happiness. These dogmatic expressions are not used to convince you, but only as a brief method of showing at once and unmistakably that my feelings towards the system are similar to those of the young lady who did not admire the moustache, and wherever she saw one felt it her duty to set her face against it. The metre is undesirable because its length is inconvenient.

In our work errors in measuring arise from five sources: 1st. The difficulty of exactly marking the end of the unit used so that the following application shall be at the same point. 2d. Imperfect alignment. 3d. Measuring out of the horizontal plane. 4th. The sag in the middle when unsupported. 5th. Irregular stretch with irregular strain.

The first and second are reduced by lengthening the unit used, and the fourth and fifth are reduced by shortening, I think the length has little practical effect on the third. Time is consumed at each application, and the number of applications and the time employed are reduced by lengthening. When on uneven ground only a small portion can be used, time is consumed in the care of the unused portion. Without being able

to give very exact figures, or what you may regard as good reasons for my conclusions, I am fully convinced that for general work in my practice the 100 feet is the happy medium giving the highest attainable degree of accuracy with the rapidity of work demanded.

Under sources of error 4 and 5 relating to sag and strain, I wish to state the result of some experiments on which my conclusions have been partially based. I have an Excelsior steel tape tested with great care by Prof. Mendenhall, of the State University, at a strain of 10 pounds, supported its entire length. When unsupported in the middle, I find 13 pounds or 3 pounds in excess of the 10, stretches it enough to take up the sag of 50 feet, and 16 pounds or 6 pounds extra, takes up the sag of 100 feet. I have another and heavier Excelsior which requires 19 pounds, or 9 pounds extra for 100 feet. By frequently testing our strength with my helpers, we learn to strain these amounts with considerable uniformity. Of course, to increase or decrease the unit used would be to increase or decrease the uniformity attainable.

Assuming that about 100 feet is the desirable length, how does this affect the use of the metre? Before entering on a discussion of this question I wish to make a statement startling for its novelty. Of course it would be unwise for this Club to lend its influence to champion every new and wild scheme which cranks may introduce. As a body we must be reasonably conservative while we keep our minds and our meetings open for the discussion of any proposition giving hope for improved methods in any branch of engineering work.

Let it then be understood that in springing upon the Club the proposition which I now make, I have consulted no other member, and none of you are required to bear any of the odium unless you hereafter commit yourselves voluntarily. I think it desirable that we adapt all our work as far as is practicable to the decimal system. Please notice my language. I say as far as is practicable. I would be reasonably conservative. I would not require the architect to plan all his buildings ten stories high, nor do I insist that each land owner shall hold even tens of feet or acres. I sometimes divide by 4 rather than to multiply by 25. Still when I have measured a distance and find that my tally pins show 16 whole tapes with an additional $17\frac{34}{100}$ feet, it is very convenient to enter it without study as 1617.34. With the 30 m. unit, how would we record this distance? Assuming 3.28 feet = 1 metre, our tally pins would show 16 applications of the tape with an additional $13\frac{9}{100}$ m. This 16 must be multiplied by 30 = 480 m., to which add 13.09 = 493.09 m. You may truly say that to multiply 16 by 30, and to add 13.09 is an easy task, and for strong-minded men it would not be difficult, but I assure you when my mind is occupied with such questions as whether to give strict distance or distribute a ± surplus, or whether to be governed by the rotten stump of the alleged sight tree or the magnetic course N. 92 E., or whether in this problem I should multiply the tangent of the hypotheneuse by the versed sine of the secant, or whether it would not, after all, be correct to divide the arc of the great circle by the sine of the cotangent, every such extra mental labor is a burden and adds opportunity for error. The metre can be noted as conveniently as the 100 foot, only by using a unit of 10 or 100 m., and I think no sane person who has had experience would propose either of them.

One other point I will speak of, because an advocate of the metre deems it of some force. It is claimed that the metre being longer, but not ten times longer, than the foot, it can be divided by 1,000, thus giving a smaller division than the .01 foot. which is too small for dividing by ten. My reply to this is, the .01 foot seems to be as small a division as land surveying demands, but if it were not so, any unit might be divided indefinitely. The accuracy demanded by the work in hand determines the fineness of the divisions, the care required in the work and the number of the figures to be used, and this is independent of the name or length of the unit. To illustrate: Take the actual distance which, expressed in feet, would be 1617.34212, and express it decimally with the least figures which shall not vary from the actual distance more than .0001 metre. In miles we have .3063148; in metres, 493.0921; in feet. 1617.342: in chains, 24.50518; the same number of figures in each case. The inch requires one more figure, 19408.105. So much with reference to the intrinsic merits of the metric unit.

I have said it will be impossible to secure the general adoption of the metric system. The fact that the unit is undesirable has contributed very little toward my reaching that opinion. Our foot and inch units have become too deeply woven into the affairs of men to make the change possible or the effort to change advisable. I say this with a full recognition of the fact that it has made great progress in a few years; that it has been adopted by some of the leading governments of the most highly civilized people, and that its nomenclature is being thrown in as a barrier between the common people and the meaning of much that is said by our best writers.

"Yes, it is true," said the palm tree, voicing the wonderful processes of nature in its reply to the startled inquiry of the vine.

"Yes, it is true; I have been 100 years attaining this growth, and in each of those years a vine has grown to my top as thou hast; each one was as surprised as thou art and as short-lived as thou wilt be." In the oil regions many an anticipated fortune, based on the progress made in drilling the first 100 feet of a well, has vanished into thin air when at 500 feet the tools were stuck in a dry hole.

In the introduction of a reform like this, which does not at once challenge the attention of the masses, it is comparatively easy to win the support of governments, and even of intelligent people, if there is plausibility on the face of it; but this reform will be a success only when the common people have learned to talk, to think and to bargain in metre units, and reformers would do well to exercise the discretion of the old Greek artists, who were never sure of the excellence of a work of art till it had been exhibited in the market place; and he who supposes that without an expenditure of more force than it will be possible to bring to bear for this purpose, the average lot or land owner can be induced to use the nomenclature of the metric system in his bargaining for land, has reached a different conclusion in his study of the human mind from that which I have reached. Several years ago, I think about 1860, the Board of Trade of Buffalo, listening to the voice of the decimal siren, decided to make all sales of grain in 100-pound units in place of bushels, and while this lasted the Buffalo papers gave the market reports in this

way. My recollection is that this continued about two weeks. If for such men the labor of converting values from 32, 56 and 60 pounds units to 100 pounds units was too great, how pleasant it must be to lot and land owners to be asked to deal with such formidable combinations as 39.37079, 3.28089, etc., etc. This obstacle, which we will call mental inertia, applies with equal force to desirable as to undesirable changes. Of course it is lamentable that the world will not consent to adopt real improvements without so much effort. We see the advantages of an improvement to be so great that when we cannot get our ideas adopted we feel justified in using such words as "stupidity," "prejudice" and many others of the large assortment of denunciatory words which seem to give temporary relief, but the fact remains that it requires force to overcome mental obstacles as well as mountains, and as engineers it would be wise to study this subject as we would any other engineering project by counting the costs and carefully considering the elements of success or failure before we rush into a project affecting such vast interests, and my plea is that this inertia of the mind—perhaps a better term would be preoccupation of the mind—causing difficulty in getting men to change from established usages, is an obstacle which it would cost more to overcome than the benefits to be derived from even a desirable change of this kind. If the reform is desirable at all, it is desirable for the same reason that a railroad is, because it will facilitate other industrial transactions, and even as the railroad is to be built only when the saving in future business is to be largely in excess of the cost of construction, so, in like manner, engineers should count the cost before attempting to break up an established usage. Those who know me best do not accuse me of an undue reverence for established usages or opinions, but when a usage or opinion has run the gauntlet of would-be reformers through the successive generations from prehistoric times, it is safe to be a little cautious about asserting that it has not in it some elements of strength and adaptation to the best interests of mankind. Usages and opinions are not valuable because old, but age is a presumption in favor of usefulness, and even when found not useful or injurious their age and necessarily firm hold on the minds of men is a factor to be considered in the cost of removal. To illustrate, let us take a closely allied subject. Our much lauded decimal notation. A very little dispassionate study will show that a duodecimal system would be far preferable. I trust you will all accept this statement without argument, but habits of thought through countless generations have run in the decimal groove, and I doubt not a simple process of duodecimal multiplication would fully tax the mental powers of any of us. The five fingers of our hands may have served many useful purposes, but the number was a mistake as the basis for a system of notation. Though we have no records of that great controversy, we may safely assume that there was a struggle of gigantic proportions when either the 12 inches were placed together to form a foot or the foot was divided into 12 parts or the yard and circle into multiples of 12—a struggle similar to the present, with probably this difference, that in that case it was the men of science who had devised a really scientific basis against the common people, whereas to-day it is men of

science introducing a reform, opposed by equally scientific men backed up by the masses. In imagination we can trace the struggle. On one side the noble enthusiasm for a grand idea, on the other, conservatism manifested in crude arguments for established methods of the fathers, backed by the impossibility of getting the masses to think at all on the subject. We see partial success of the reform among men of exceptionably attainments, such as mechanics and astronomers, but the palm tree lives, and twelfth divisions, and calculations make little progress, while nearly the whole world is to-day trying to extend the unscientific, comparatively inconvenient finger-counting method which came in with the first dawn of savage intelligence—a method of which we may truly say what we cannot say of any unit of measure, that if all records of it were wiped out the savages would count their fingers and reproduce it. A system with 12 in place of 10 for its base would be much the best, but it is not likely any of us would advise an attempt to make the change.

The principal object of our meetings is to devise and extend better methods of work, in other words, to promote reform.

Between the improvements we would all advise working for, and an effort to adopt the duodecimal system for calculations or a project to build a railroad to the north pole, where shall we draw the line? In the language of P. Henry, "I know not what others may say, but as for me," I would draw the line a long way below an attempt to establish a new unit. The effort to introduce a new unit is not simply a waste of energy, it is a positive damage, because every success achieved is adding to the confusion we already have. The vine may serve some useful purposes, but when it dies its branches are unsightly.

In our real estate records you can find such dimensions as chains, links, rods, feet, inches, miles, acres, roods, square rods, square feet and both vulgar and decimal fractions of each, the multiplicity of which are confusing, and to make the confusion complete requires only the introduction of a few dozen more ending in "tre." There was some excuse for Gunter to introduce the 100-link chain to adapt land measure by the acre to the decimal system, but he took a unit easily convertible into the previously used units; in other words, he did not repeat the Canutism of manifesting an utter contempt for that which was established; while the authors of the metre evidently having that contempt, manifested it by devising a unit inconvertible into any established unit, thus adding to the difficulty of making the change, while the change could only be useful by saving labor, after it should supplant other methods. Could blind rage and educated stupidity have blundered more than this? If provocations and motives were a part of my theme much might be said in defense of those men, but recognizing that good motives are so plentiful in a certain country as to be used for paving stones, it is wisdom for us to ignore them and discuss things as we find them with reference to their probable usefulness.

I am aware that the metric system is fascinating, with its method of combining measurements of all extensions and weights, and we may assume with some show of reason that had the schoolmen been on earth at the beginning, and had been given the superintendence of affairs, many beautiful theories would have been worked out, and the face of nature

and the condition of human society would have been quite different from what we find. The rivers which are so wastefully running away to the sea and wearing channels where none are needed, might just as well have saved us so much expense in digging canals. A universal language would have been adopted without a dissenting vote by such wise managers. Fine theories are well, but to be worthy to supplant the established, a system must be well devised and its superiority to the established must be great to compensate for the change. There are hoary-headed errors which it is to be hoped we will outgrow, but there was much worldly wisdom in that old farmer who refused to allow his wheat to be destroyed because his enemy had sown a few tares in the field. We can imagine he indulged in some justifiable uncomplimentary remarks, but he displayed the wisdom of a sensible engineer by counting the cost, gracefully accepting the situation and abiding his time.

I have said the theory of the metric system is fascinating. "Why ma," said the little girl, as with dilated eyes she had been listening to her mother's description of heaven, "Why ma," said she, "if it is a suck in, what a big suck in it is." Though I was at first fascinated by the system, and disposed to work for its adoption, I now feel it to be a great mistake, and a mournful mistake, because I see in it that which would not be an improvement on what we have, if adopted, and that a partial adoption, which is sure to be the only result of effort, will only result in more confusion where now we have too much. And my feelings are still more mournful because I see that had the foot been adopted as the unit, so much good might have been done, with no harm, by the efforts which have been put forth.

A REVISED TIME-TABLE FOR LIGHTING PUBLIC LAMPS.

[By Julius M. Howells, Member of the Western Society of Engineers.]
[Read April 6, 1886.]

One of the tedious tasks that falls to the engineer of small cities is that of making out time-tables, from year to year, for the lighting of public lamps. This task might seem comparatively easy to one who had never undertaken it, and hardly of sufficient importance to warrant making it the subject of a paper.

It would seem but a simple affair to procure a copy of the tables used in Philadelphia and elsewhere and follow the short but comprehensive directions printed with those tables. These directions, however, are not definite and particular enough for an efficient distribution of light over the time required to be lighted, and allow a waste at other times: for which reason I began at the bottom of the whole matter, and from a series of experiments on the light afforded by twilight and the various phases of the moon made out a schedule differing considerably from other tables in common use.

This subject deserves attention, for certainly hundreds of lamps to be burning while the streets are amply lighted from the natural source is a great waste. Also is it very inconvenient to have no light at times,

either naturally or artificially. More particularly does this subject seem important at the present time, as gas-light may soon be generally superseded by electric light, when lighting and extinguishing requires but the movement of the hand. Thus, as an instance, when a city is depending on a half moon for light, and clouds should come up to obscure its light, it would be but a simple operation to bring the public lamps into effect.

In lighting cities by any method it is very desirable to have an economically disposed lighting schedule. If a city is limited to 2,000 or 2,200 hours of lamp-light for the year, which latter amount is ample, it requires a very nice distribution of light to avoid, at times, total darkness. Some cities in public lighting take no cognizance of moonlight, and street lamps blaze all night long; their flames look pale enough, almost casting shadows in the bright light of a harvest moon. This thriftless disregard for economy is inexplicable, when with a properly organized lamp-lighting force a tenth part of the light burned during moonlight nights, put at the disposal of an efficient officer—say, the chief of police—would light the nights when clouds obscure the moon, and the whole period of moonlight nights would be just as well lighted. Such an officer gets ample warning from the signal service reports, and from an outlook for sudden changes of weather, and could order lamps lit and have them burning almost before the sky could become overcast.

Some cities light up in the evening, and extinguish at, or soon after, midnight. In such a place one who finds it necessary to venture out after lights are extinguished, unless provided with a lantern, finds out the inconvenience of such a plan, often to his sorrow, if not his peril.

It is not my object to advocate the burning of more gas than the finances of a place will warrant. Some towns find it necessary to go without public lamps altogether. But I do urge, for cities where public lamps are in use, that more attention be given to securing an economical distribution of light.

I used this plan in making out my schedule: first, by the adoption of a minimum limit for daylight which, in the particular class of a city considered, is no more than sufficient for people to see to walk and drive; second, to determine by experiment what proportion of twilight will furnish more light than this minimum limit; and what is the least phase of the moon to be used and how high must it be at its various phases to furnish more light than this minimum limit. After these data had been satisfactorily determined, I used such part of the moonlight and such per cent. of twilight determined as above, and set aside about 125 hours to be used when clouds darkened the moon and twilight. In reserving these extra hours their number is, of course, influenced by local climate.

The conditions under which our experiments were made were these, viz., a city of 18,000 inhabitants, lighted by 266 public gas lamps of 16 candle-power; width of streets from 50 to 80 feet; business houses on the broadest streets and standing on line of street; the buildings in blocks so that the moon does not shine between them; there are no shade trees on business streets. The residence streets average 66 feet wide; houses in some instances stand on the line of the street, but are separate, allowing the moon to shine between them; here there are many shade trees.

As to climate, about the average amount of cloudy weather for an inland city, and little fog or smoke.

First as to moonlight. Under these conditions we find when the moon is full and half an hour up it shines high up on the faces of business buildings facing East and West, and at this phase and time, after raising the minimum limit of light, is reflected to the street. Here, also, shop windows may add much to the light. On resident streets also, when the moon is full and half an hour up it shines between the houses and through the trees as well as being somewhat reflected, furnishing light more than the minimum limit. Next as to the *least* phase of the moon when its light exceeds the limit and how high must it be. Our experiments proved that the moon at one day larger than at one-eighth and two hours high will give light in the streets to exceed the minimum. Also that the moon for lighting is practically full for three days.

We now proceed to schedule our conclusions for those days first, when the moon would affect the time of lighting and extinguishing. Also adopting this rule as conforming to the conclusions drawn; viz., one hour and forty minutes equals the time the moon should be up at either quarter; and increasing this time toward new moon and diminishing toward full moon ten minutes each day; make two hours the greatest limit and leaving the least limit to fix itself by reaching the time of full moon all night.

The following is the moonlight schedule:

(COPIED FROM CALCULATIONS FOR JUNE, 1885.)

Day of month	1	2	3	4	5	6	7	8	12	16	17
Phase of moon	...	...	...	...	¼	...	...	...	N'w	...	...
Time to light before moon sets, or to extinguish after moon rises	h m 1 00	h m 1 10	h m 1 20	h m 1 30	h m 1 40	h m 1 50	h m 2 0	h m ...	h m ...	h m ...	h m 2 00
Time moon sets	...	...	...	...	...	...	...	...	...	11 17	11 51
Time moon rises	10 13	10 48	11 23	11 56	12 28	1 00	1 32	2 08	...	...	...
Time to light lamps	...	...	...	...	...	...	...	...	...	...	9 51
Time to ext'g'sh "	11 13	11 58	12 43	1 26	2 08	2 50	3 32	...	...	...	...

Day of month	18	19	20	21	22	23	24	25	26	27	28	29	30
Phase of moon	...	¼	...	...	...	...	...	...	...	F'll	...	...	...
Time to light before moon sets, or to extinguish after moon rises	h m 1 50	h m 1 40	h m 1 30	h m 1 20	h m 1 10	h m 1 00	h m 50	h m 40	h m 30	h m 30	h m 30	h m 40	h m 50
Time moon sets	12 24	12 56	1 29	2 05	2 43	3 23	...	...	...	...	...	...	...
Time moon rises	...	...	...	...	...	...	...	...	...	...	8 13	8 50	9 25
Time to light lamps	10 34	11 16	12 00	12 45	1 33	2 33	...	...	...	...	...	...	...
Time to ext'g'sh "	...	...	...	...	...	...	...	...	...	...	...	9 30	10 15

Before considering twilight let us look at the "Directions for Public Lighting" used by the City of Philadelphia, from which are made standard tables. They are: "Light half hour after sun sets. Light one hour before moon sets. Extinguish one hour before sun rises. Extinguish one hour after moon rises."

From what has been shown regarding the light afforded by the moon in all its phases, these directions must at once appear altogether too general. As to twilight, when we remember that the length varies from two hours and six minutes in June to one hour and thirty-two minutes in September, it is easy to see that the use of *any constant* the year around gives no uniform limit of light.

In my experiments the length of twilight was determined for each day of the year and 60 per cent. of it used, as found to be sufficient for street-lighting. The time when twilight began and ceased was conveniently determined by a movable planisphere of the heavens, accurately made by Aldison H. Study, of Richmond, Ind., to whom I am indebted for its use. Thus we schedule the calculations for twilight as for moonlight, setting in their proper columns the results taken from the above table for moonlight. In the schedule the moonlight results are separated from the twilight results by a *.

Days of month	1	2	3	4	5	6	7	8	9	10
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
60 per cent. of twilight	1 14	1 14	1 14	1 15	1 15	1 15	1 15	1 15	1 15	1 15
Time sun sets	7 22	7 23	7 23	7 24	7 25	7 26	7 26	7 26	7 27	7 27
" " rises	4 33	4 33	4 32	4 32	4 32	4 32	4 31	4 31	4 31	4 31
Time to light lamps, to nearest 5 min.	8 35	8 35	8 40	8 40	8 40	8 40	8 40	8 40	8 40	8 40
Time to extinguish, to nearest 5 min.	11 15	12 00	12 45	1 25	2 10	2 50*	3 15	3 15	3 15	3 15
Number hours lighted	2 40	3 25	4 05	4 45	5 30	6 10	6 35	6 35	6 35	6 35

Days of month	11	12	13	14	15	16	17	18	19	20
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
60 per cent. of twilight	1 16	1 16	1 16	1 16	1 16	1 16	1 16	1 17	1 17	1 17
Time sun sets	7 37	7 28	7 28	7 29	7 29	7 30	7 30	7 31	7 31	7 31
" " rises	4 31	4 31	4 31	4 31	4 31	4 31	4 31	4 31	4 31	4 31
Time to light lamps, to nearest 5 min.	8 45	8 45	8 45	8 45	8 45	8 45*	9 50	10 35	11 15	12 00
Time to extinguish, to nearest 5 min.	3 15	3 15	3 15	3 15	3 15	3 15	3 15	3 15	3 15	3 15
Number hours lighted	6 30	6 30	6 30	6 30	6 30	6 30	5 25	4 40	4 00	3 15

Days of month	21	22	23	24	25	26	27	28	29	30
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
60 per cent twilight	1 17	1 17	1 17	1 17	1 17	1 17	1 17	1 17	1 17	1 17
Time sun sets	7 31	7 32	7 32	7 32	7 32	7 2	7 32	7 32	7 32	7 32
" " rises	4 31	4 32	4 32	4 32	4 32	4 32	4 32	4 32	4 32	4 32
Time to light lamps, to nearest 5 min.	12 45	1 35	.....	..	...	....	...	....	8 50	8 50
Time to extinguish, to nearest 5 min.	3 15	3 15	.....	....	....	....	..	...	9 30	10 15
Number hours lighted	2 30	Not lighted.			...	....	....	..	...	1 25

In combining the two foregoing tables for moonlight and twilight, it is obvious where the one should leave off, and the other commence, as the point of change is where the two tables approach the same time. Next we calculate the hours of gas-light, and when they are for any night less than one hour and 30 minutes it is not worth while to light up; unless such short interval of darkness occurs early in the evening, when many people are out, when it may be best to light up for a single hour.

Lastly we foot the hours lighted for the entire year, and find we have about 2,000 hours. If our contract with the gas company is for 2,200 we have still some to spare. We can make our table to light 15 min. earlier through the entire year, which we had better do, leaving the extinguishing at the first schedule time, except where, on account of moon, we extinguish before eleven o'clock, on which nights we might extinguish ten minutes later.

This completes our table. We again foot up the hours lighted, and have still some 125 hours which are reserved to be ordered used when clouds obscure the moon.

I have the length of nights, twilight, etc., expressed graphically on a large sheet, from which it is a simple operation to read off the minimum limits of light as shown by the above twilight table.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JUNE 16, 1886 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M., Mr. E. W. Howe in the chair, nineteen Members and three visitors present.

The record of the last meeting was read and approved.

Mr. C. H. Haswell was elected an Honorary Member. Mr. Arthur Winslow was elected a Member of this Society.

Mr. Ephraim Harrington was proposed for membership, recommended by H. Manley and H. L. Eaton.

Mr. Gabriel A. Bobrick was proposed for membership, recommended by C. S. Parsons and S. E. Tinkham.

The amendments to the Constitution proposed in writing and adopted at the last regular meeting were adopted by the following vote :

Article Fourteen—Affirmative, 13 ; negative, 0.

Article Fifteen—Affirmative, 11 ; negative, 0.

The Committee on Furnishing Rooms and Transfer of Library reported that the duties assigned it had been completed at a cost of $188.09. The report of the Committee was accepted, and the Committee discharged.

On motion of Mr. H. Manley it was voted : That a committee of three be appointed by the Chair to nominate an additional representative on the Board of Managers of the JOURNAL OF THE ASSOCIATION OF ENGINEERNG SOCIETIES. The Committee as appointed consists of D. Fitz Gerald, F. P. Stearns, F. O. Whitney.

On motion it was voted : That the July and August meetings be omitted.

Mr. A. D. Marble read a paper on "The Improvement and Drainage of the Spicket River Valley, Lawrence, Mass."

Mr. Desmond FitzGerald described the work done in the removal of the shallow flowage from the Sudbury River stowage basins, Boston water-works.

The bad position in which the city of Boston was placed in 1872 from lack of an adequate supply of water was briefly alluded to, after which a short account was given of the methods of constructing the basins on the Sudbury River supply, which consisted in cutting off the trees, damming up the streams and filling the basins, with but little attention to the loam on the sides of the valleys or the condition of the bottom.

The basins were filled in 1878 and 1879. In a few years a very bad taste developed in the water, rendering it unfit for domestic use. The different growths of algæ and spongilla were described and some of their habits given. Then followed an investigation by a sanitary committee, who decided that the loam and shallow flowage in the basins were largely accountable for the trouble. An appropriation of $125,000 for removing the shallow flowage from Basin III. and $80,000 for Basin II. was secured. In 1883 the speaker was charged with the duty of remodeling the shores of Basin II., and a favorable working season enabled the work to be completed before the ground was frozen. The plan consisted in brief in filling up the shallow portions and excavating others so as to leave nowhere around the margin of the lake less than ten feet depth of water, and with gravel slopes exposed to the water.

In carrying out this plan the shore lines were very much straightened by filling the shallow bays, cutting off shallow points, etc.

To accomplish this result, more than 130,000 cubic yards of loam and gravel were moved, and a large amount of rip-rapping placed. The total cost came inside of the estimate, and a rather more comprehensive plan was carried out than originally intended.

Basin III. is now under the same course of treatment, but here nearly 300,000 cubic yards of material must be moved. Ten contracts are now being executed, and the price varies from 22 to 31 cents per cubic yard.

The speaker expressed the opinion that the improvement would probably pay for its cost in insuring a better condition of the supply, and showed his reasons for believing the changes would affect the temperature of the water and the wash on the sides of the basin, though it was rather soon to say definitely how far the improvements would stop the growth of algæ and prevent the fermentation of the water in the basins. The work is being pushed vigorously and under favorable conditions for its early completion. The gravel slopes are mostly three to one, and the embankments are built only one foot above extreme high-water mark. The stumps were found to be offensive in many cases, and they are all to be removed, even where found below the limits of shallow flowage.

The Committee appointed to nominate an additional representative on the Board of Managers of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES reported the name of Prof. Winfield S. Chaplin, and a ballot being taken, he was declared elected.

[*Adjourned.*] H. L. EATON, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

KUTTER'S FORMULA AND ITS APPLICATION TO CIRCULAR SEWERS.

By Robt. Moore and Julius Baier, Members of the Engineers' Club of St. Louis.

[Read April 7, 1886.]

In the JOURNAL for December, 1881,* was given a series of tables showing the diameters of circular sewers for various conditions of grade and drainage area. As there stated, these tables were constructed for actual use in the St. Louis Sewer Department, and were found to be of great practical utility and convenience. The formula used in their construction was that of Weisbach transformed to suit the special case of a circular conduit with a depth of water equal to three-fourths the diameter. Upon re-examining these tables with a view to enlarging their scope and increasing their value, it has seemed best to wholly recast and recompute them upon a different basis and from another formula. The reasons for so doing are:

First. The height of water used in these tables—three-fourths the diameter—being a purely arbitrary point and corresponding to no natural limit, does not commend itself as a satisfactory basis for tables of this kind. Nor do the limits of full, two-thirds full and half full, used in other tables, seem to be any better: the two latter being open the same objection already named, that they are purely arbitrary; and the first because, as noted hereafter, no sewer is ever full as a matter of fact except when put under pressure, and thereby subjected to strains which it ought never to bear.

In searching for a more natural and satisfactory basis, the one most clearly indicated by the facts themselves is the point of maximum discharge, which, as will be shown further on, corresponds to neither of the limits already mentioned, but, according to the formula used in this paper, is reached when the height of water is about 93 per cent. of the diameter. At this point, and this only, we reach the full value of the conduit to meet the end for which it is built, and can compare its capacity correctly with other works of the same kind as we cannot do at any other point.

* Tables for determining the proper sizes of sewers. By Robert Moore. JOURNAL Assoc. Eng. Soc., Vol. 1, p. 64.

And if it be objected that this extreme limit does not give us the margin for safety which is given by the other limits named, and is needed in all engineering structures, we have only to answer that this margin is given in a much more scientific and satisfactory manner by simply adding a definite percentage to the required discharge and proportioning the sewer therefor. In this manner any desired factor of safety can be used and carried uniformly through the system much more easily than by any other method. The point of maximum discharge was, therefore, adopted as the basis of the proposed revision.

Second. The formula of Weisbach, though derived from actual experiments, many of them by himself, appears in the light of later investigations and larger experiments to represent correctly but a limited range of facts, and to be unsound when extended over the wider scope contemplated in the present instance. Admirably simple and convenient as it is, experimenters since his time have shown that it is much too simple to fully express the complicated group of facts which determine the flow of water in channels of varied inclinations, sizes, shapes and materials. So that for a comprehensive table, a formula of wider range is required.

In order properly to understand the relations to each other of the various formulas for the flow of water in open channels, and the development which they have undergone, it is necessary to go back to the formula first proposed by Chezy, a French engineer, in the latter part of the eighteenth century, to wit:

$$V = c\ \sqrt{R\, s},$$

in which

V = Mean velocity of the water in feet per second.

R = "Hydraulic mean radius"

$= \dfrac{\text{Area in square feet of the cross-section of water.}}{\text{Wetted perimeter in lineal feet.}}$

s = Slope $= \dfrac{\text{Fall.}}{\text{Length.}}$

c = A co-efficient determined by experiment.

To this general form nearly all the later formulas may be reduced, the only differences being in the values given by different investigators to the co-efficient c. Thus in Weisbach's formula we have

$$V = \sqrt{\frac{2g}{\alpha\left(1 + \dfrac{\beta}{v}\right)}}\ \sqrt{R s} = c\sqrt{R\, s}$$

in which, in addition to the symbols already given, we have

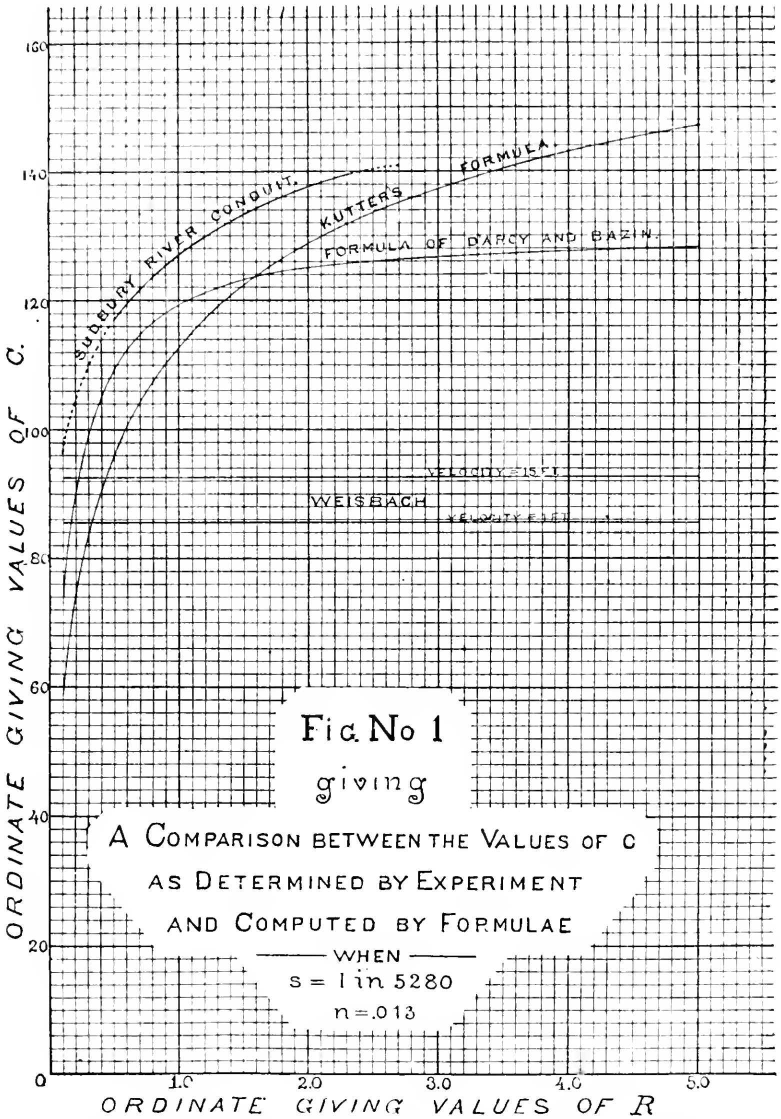
$2g$ = Acceleration due to gravity,

α and β = Empirical constants.

In this formula it will be observed that the co-efficient c is not a constant, but varies with the velocity v. The values given by Weisbach to the constants α and β are such, however, that the variations in c are of comparatively small importance, varying for English measures between 84 and 93, or about 10 per cent. The values of these constants were, as he tells us, deduced from 255 experiments, most of which were made by himself.* But it would appear that the experiments must have all been

* See Weisbach's Mechanics of Engineering, Vol. 1, p. 967. Coxe's translation.

made upon small channels with nearly uniform hydraulic radius. For while when applied to small channels it gives results agreeing very



closely with the facts when applied to larger ones, exceeding say a 12-inch pipe, the calculated velocities are much too small.*

* For a series of experiments with 12-inch pipe, agreeing very closely with the formula, see account of gaugings of Compton avenue sewer, St. Louis, Mo., in *American Engineer*, Vol. 1, p. 159, October, 1880.

Among the first to note this defect of the Weisbach formula and to propose a correction were the French engineers Darcy and Bazin, who made an extended series of experiments at the expense of the government, the results of which were first published in 1865. The formula proposed by them is

$$V = \sqrt{\frac{2g}{\alpha\left(1 + \frac{\beta}{R}\right)}} \sqrt{R s} = c \sqrt{R s}$$

in which R takes the place, in the expression for c, which is given by Weisbach to v, and α and β become variables changing with the roughness of the sides of the channel ; so that nothwithstanding their similarity of appearance the two formulas express laws which are very unlike.

A further modification of the formula was proposed by Ganguillet and Kutter, two Swiss engineers, who, starting where Darcy and Bazin left off, took in a still wider range of facts and gave a much more complicated expression for c. Their formula, with values of the constants for measures in English feet, is—

$$V = \left[\frac{41.6 + \frac{1.811}{n} + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{n}{\sqrt{R}}}\right] \sqrt{R s} = c \sqrt{R s}$$

in which, besides the terms already explained, there appears a new variable n, whose value depends upon the roughness of the sides of the channel, and which is therefore called the "co-efficient of roughness."

To better show the precise effect of these various modifications of the fundamental formula, as well as how the results agree with well ascertained facts, Fig. 1 has been constructed. In this the values of c obtained from the different formulas are plotted as curves, and along with them another curve giving the values of the same co-efficient deduced from the experiments of Messrs. Fteley and Stearns in the Sudbury conduit of the Boston Water-Works—one of the most carefully conducted and valuable series of experiments on record.*

In applying the formulas s was taken as $\frac{1}{5280}$, the actual grade of the Sudbury conduit, and Kutter's n was taken as .013, the customary value for surfaces of brickwork. In plotting from Weisbach's formula the difficulty occurred that inasmuch as the values of c are constant for different values of v, without regard to changes in R, they cannot be represented by any single line, but only by a series of lines, parallel to the axis of R.

To indicate the field in which these lie, two lines have been drawn for limiting values of v, viz.:

For $v = 1$ ft. per sec. and $c = 84$,
and for $v = 15$ ft. $c = 92.6$.

The intermediate values of c will lie between these two lines. The values for the Sudbury conduit are taken directly from the table given by Messrs. Fteley and Stearns, the full line indicating values given by direct experiment and the dotted line values given by computation.

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* See Transactions American Soc. Civ. Engrs., 1883, p. 115: also, Official Report, Additional Supply, Boston Water-Works, 1882, p. 92.

TABLE I.

GIVING VALUES OF "C" IN KUTTER'S FORMULA WHEN s = .001.

VALUES OF N.

R.	.009	.010	.011	.012	.013	.015	.017	.020	.0225	.025	.030	.035	R.
.1	108.3	93.8	82.2	72.7	65.0	53.2	44.6	35.5	30.0	25.9	20.1	16.3	.1
.2	129.5	113.1	100.0	89.1	80.2	66.3	56.2	45.2	38.6	33.6	26.3	21.5	.2
.3	141.8	123.8	111.0	98.8	90.2	75.0	63.4	51.8	44.6	38.4	30.3	25.1	.3
.4	150.3	132.5	118.0	106.0	96.2	80.4	68.8	56.2	48.4	42.4	33.7	27.8	.4
.5	156.8	138.6	123.8	111.2	101.2	85.1	72.8	60.0	51.8	45.4	36.2	30.0	.5
.6	161.9	143.3	128.3	115.7	105.3	88.8	76.4	62.9	54.5	48.0	38.5	32.0	.6
.7	166.1	147.4	131.9	119.3	108.7	92.0	79.3	65.4	56.9	50.2	40.3	33.6	.7
.8	169.7	150.8	135.1	122.3	111.6	94.6	81.9	67.7	59.0	52.2	42.0	35.1	.8
.9	172.8	153.7	137.8	125.1	114.2	97.0	84.2	69.7	60.8	53.8	43.4	36.3	.9
1.0	175.4	156.2	140.5	127.4	116.5	99.1	86.0	71.5	62.5	55.4	44.9	37.7	1.0
1.2	180.0	160.4	144.6	131.5	120.4	102.7	89.4	74.5	65.3	58.1	47.1	39.7	1.2
1.4	183.6	164.0	147.9	134.7	123.7	105.7	92.2	77.0	67.7	60.2	49.2	41.5	1.4
1.6	186.7	167.0	150.8	137.4	126.2	108.2	94.5	79.3	69.9	62.3	51.0	43.2	1.6
1.8	189.2	169.5	153.2	139.7	128.7	110.3	96.6	81.1	71.6	64.0	52.6	44.6	1.8
2.0	191.4	171.6	155.4	141.8	130.5	112.3	98.4	82.9	73.4	65.5	54.0	45.9	2.0
2.2	193.3	173.5	157.3	143.7	132.3	114.0	100.0	84.3	74.7	66.9	55.2	47.0	2.2
2.4	195.6	175.2	159.0	145.3	133.9	115.4	101.4	85.6	76.0	68.1	56.3	48.0	2.4
2.6	196.7	176.8	160.5	146.8	135.3	116.8	102.8	87.0	77.1	69.2	57.4	49.0	2.6
2.8	198.0	178.2	161.8	148.1	136.7	118.0	104.0	88.2	78.2	70.3	58.4	49.9	2.8
3.0	199.3	179.4	163.2	149.3	137.9	119.2	105.1	89.3	79.2	71.3	59.2	50.6	3.0
3.4	201.7	181.7	165.3	151.4	140.0	121.3	107.1	91.1	81.0	73.0	60.8	52.0	3.4
3.8	203.7	183.6	167.2	153.3	141.8	123.0	108.8	92.7	82.5	74.5	62.3	53.5	3.8
4.2	205.4	185.3	168.8	155.0	143.4	124.6	110.3	94.3	83.9	75.8	63.5	54.7	4.2
4.6	207.0	186.8	170.3	156.4	144.8	125.9	111.6	95.4	85.2	77.0	64.7	55.7	4.6
5.0	208.3	188.1	171.6	157.7	146.0	127.2	112.9	96.6	86.3	78.1	65.7	56.7	5.0

Kutter's formula for velocity is

$$V = C\sqrt{R\,s} = \left\{ \frac{41.6 + \dfrac{1.811}{n} + \dfrac{.00281}{s}}{1 + \left(41.6 + \dfrac{.00281}{s}\right)\dfrac{n}{\sqrt{R}}} \right\} \sqrt{R\,s}$$

An inspection of these several curves shows that while at one point the values of c deduced from Weisbach's formula coincide exactly with the Sudbury experiments at all other points, they differ from them very

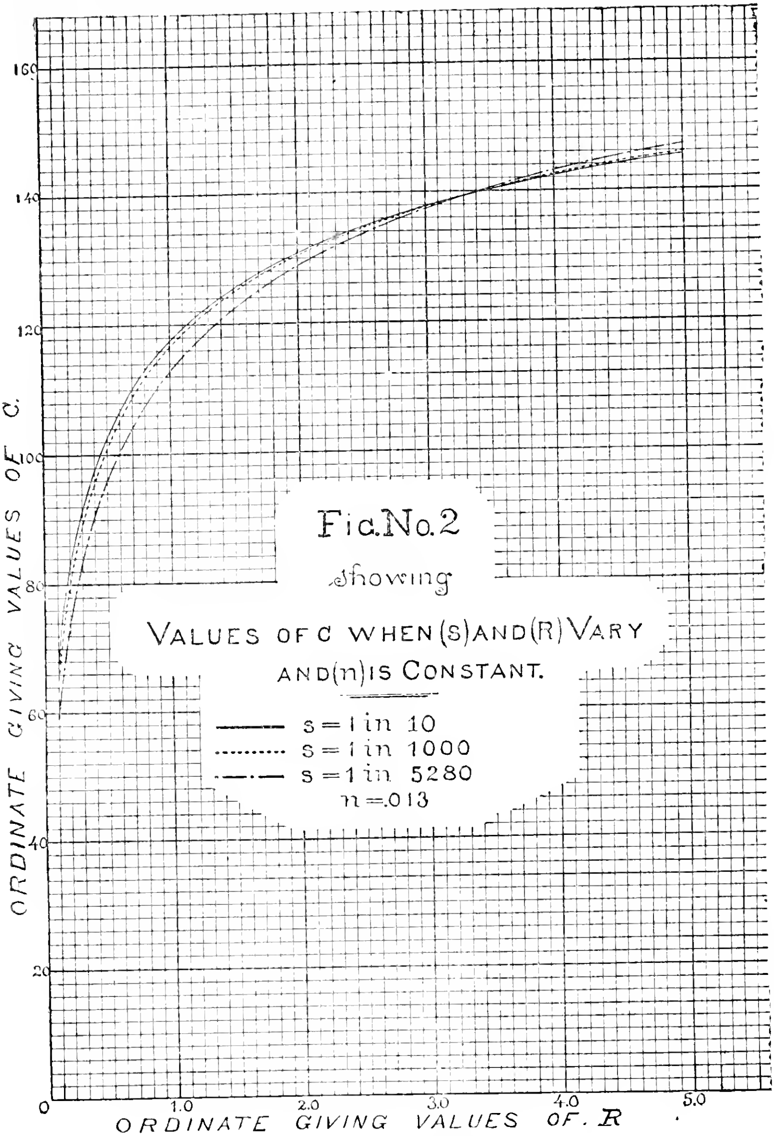
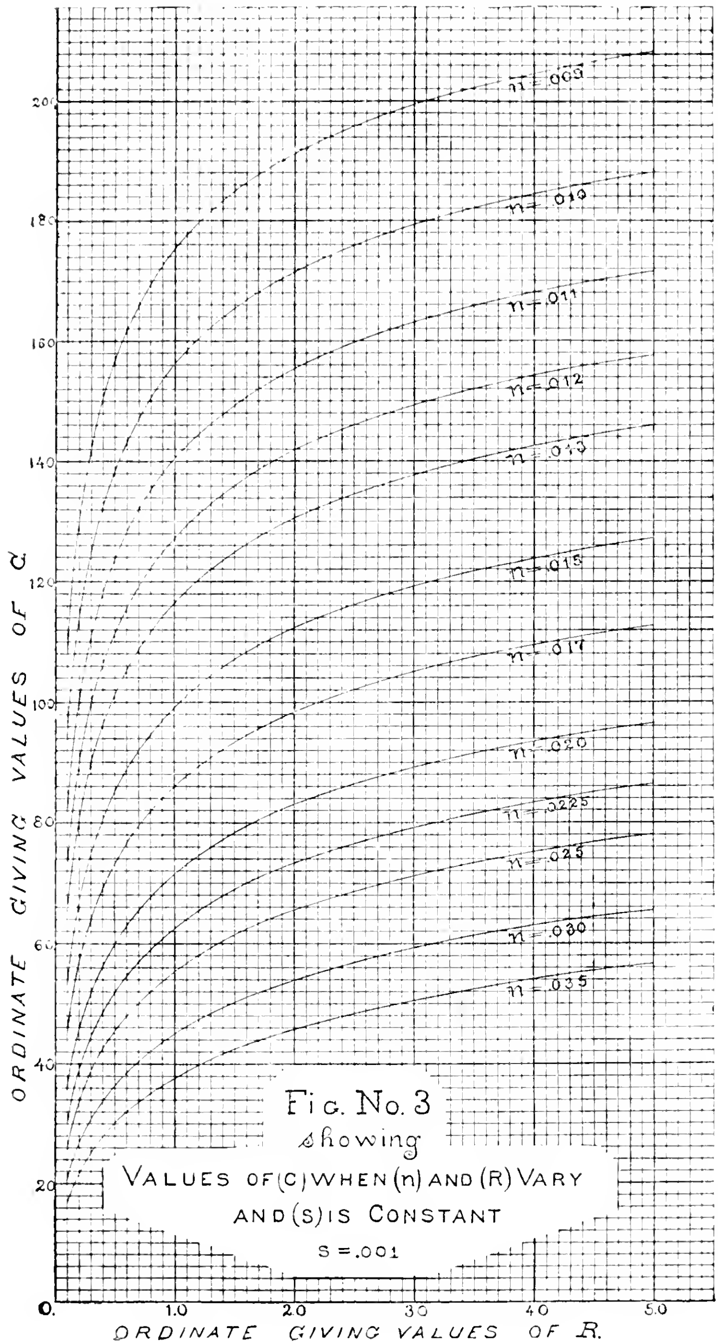


Fig. No. 2
showing
VALUES OF C WHEN (S) AND (R) VARY AND (n) IS CONSTANT.

widely and are governed by a wholly different law. The curves of the two other formulas show a much closer correspondence to the Sudbury curve, that of the Kutter formula being considerably the closest, showing


n = .009
n = .010
n = .011
n = .012
n = .013
n = .015
n = .017
n = .020
n = .0225
n = .025
n = .030
n = .035
200
180
160
140
120
100
80
60
40
20
0.
1.0
2.0
3.0
4.0
5.0
ORDINATE GIVING VALUES OF C
ORDINATE GIVING VALUES OF R.
Fig. No. 3
showing
VALUES OF (C) WHEN (n) AND (R) VARY
AND (S) IS CONSTANT
S = .001

that on the whole it most nearly represents the actual facts. It was, therefore, selected as the one to be used in the proposed revision.

Upon inspection of Kutter's formula, it will be noted that the value of c depends upon three quantities, n, s and R, each of which may vary independently of the other. To show the relative importance of these three variables as affecting the value of c, figures 2 and 3 were constructed. Figure 2 is a graphical presentation of the values of c for different values of R and s, n being taken as constant and equal to .013. The values of s taken are 1 in 10, 1 in 1,000 and 1 in 5,280, and cover the whole range of ordinary cases. The proximity of the several curves in the figure shows that the effect of variations in s upon the value of c is not important, the extreme effect in the three cases shown in the figure not exceeding 3½ per cent., and that for all ordinary cases, extremely flat slopes alone excepted, s may, without material error, be treated as a constant.

The effect of the other two variables is seen in Fig. 3, in which are shown the values of c for different values of R and n, s being taken as constant and equal to .001. The wide divergence of the curves for different values of n shows the effect upon c of changes in the value of n to be very great. And in using Kutter's formula more depends upon choosing a correct value for n than upon anything else.

In the application of this formula to actual cases, Fig. 3 and Table I, which both present the same facts, only in different forms, will be found of great practical convenience, for by means of them values of c for different values of R and n can be found at once without computation, and the chief difficulty in using the formula, which is a very awkward one, be avoided.*

It has been already stated that in a circular conduit not under pressure the maximum velocity and maximum discharge occur before it is quite full. To show the law of these facts more clearly we have constructed Figure 4, in which are two curves, one showing the variations in the velocity as the water rises in the conduit, and the other the corresponding variations in the discharge. The same facts are given numerically in Table II. In both the diagram and the table the maximum velocity and the maximum discharge are taken as unity, and the velocity and discharge at other points given as a percentage. Both curves were computed from Kutter's formula, taking $n = .013$ and $s = .005$. As will be seen from the diagram the greatest velocity occurs when the depth of water is 81 per cent. of the diameter. At this point the angle of the empty segment is $102^\circ\ 33'$ and R has its maximum value of .3043 times the diameter. The greatest discharge occurs somewhat later when the

* A study of this figure will also indicate the chief defect of the formula pointed out by Mr. Ellis in Transactions of Am. Soc. Civil Engineers for 1877, viz., its failure when applied to very large streams, such as the Mississippi River. It will be noticed that the curves for different values of n, which indicate the effect of the roughness of the sides, continue to diverge with the increasing values of R, whereas they ought after a time to converge. For as a fact, as the channel enlarges the effect of different degrees of roughness of the sides becomes less and less, and the curves representing it should finally merge into one. This, however, is only another illustration of the extreme difficulty of framing a mathematical expression to represent fully any complicated group of facts, and the great need of caution in using even the most approved formulas.

TABLE II.

SHOWING THE RELATIVE VELOCITY AND RELATIVE DISCHARGE FOR VARIOUS DEPTHS OF WATER IN A CIRCULAR CONDUIT.

Depth of water.	Relative velocity.	Relative discharge.
.1	.28	.016
.2	.48	.072
.25	.57	.118
.3	.64	.168
.4	.76	.302
.5	.86	.450
.6	.93	.620
.7	.98	.776
.75	.99	.850
.8	.99	.912
.81	1.00	.924
.9	.98	.992
.93	.96	1.000
1.00	.86	916

depth is 93 per cent. of the diameter. At this point the angle of the empty segment is 60 degrees and R equals .2914 times the diameter.

In planning sewers the question of greatest practical importance, and to which all others converge, is to determine the proper size or diameter of the conduit necessary to meet certain fixed requirements of discharge and slope. But with Kutter's formula this happens to be the question of all others most difficult to answer. Owing to the complicated nature of the formula, it is not practicable to form an equation for the diameter in terms of the discharge and slope alone. By assuming values for the slope, diameter, and co-efficient of roughness, we can compute the velocity, and from this the discharge, which is simply velocity multiplied by cross section. But if, on the other hand, we desire to find the diameter corresponding to certain conditions of slope, discharge and roughness of channel, we can only do it by a series of approximations: *i. e.*, by assuming a diameter and computing the discharge, and keep trying until a diameter is found which gives the discharge required.

To overcome this difficulty was the object of figure 5, which was constructed by computing the maximum discharge in cubic feet per second for various diameters and grades and joining the points thus found by curves. From these curves we can easily work backwards and find directly the diameter corresponding to given conditions of discharge and slope as we cannot from the formula, and Table III. was constructed in this manner by scaling from the diagram. It is, of course, open to the objection that the results are not mathematically exact, but as they are quite as exact as the data themselves, in which perfect accuracy is impossible, the objection is without force.

Throughout the computations the value of n was taken at .013, the ordinary value for channels of brickwork. As will be seen from Figure 1, this value gives velocities less than the Sudbury experiments, and errs, therefore, on the side of safety.

In addition to the discharge curves, Figure 5 contains two curves which indicate velocity. These are: First, a curve connecting points of discharge and diameter, for which the velocity is 15 feet per second. Experience shows that in sewers of ordinary brickwork where the

TABLE III.

GIVING DIAMETERS IN FEET OF CIRCULAR SEWERS FOR VARIOUS INCLINATIONS AND RATES OF DISCHARGE.

Sewers full to point of Maximum Discharge.

Cubic feet per second.	FALL OF SEWER IN FEET PER 100.													Cubic fee per second.
	.10	.15	.20	.30	.50	.75	1 00	1.5	2.0	3.0	4.0	6.0	10.0	
1....	.9	.9	.8	.8	.7	.7	.6	.6	.6	.5	.5	.5	.4	1
2 ...	1.2	1.1	1.1	1.0	.9	.8	.8	.7	.7	.7	.6	.6	.5	2
3 ...	1 4	1.3	1.3	1.2	.11	1.0	.9	.9	.8	.8	.7	.7	.6	3
4 ...	1.6	1.5	1.4	1.3	1.2	1.1	1.0	1.0	.9	.8	.8	.7	.7	4
5....	1.7	1.6	1.5	1.4	1.3	1 2	1.1	1.0	1 0	.9	.9	.8	.7	5
10....	2.2	2.0	1.9	1 8	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	.9	10
15....	2.6	2.4	2 3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	15
20 ...	2.9	2.6	2.5	2.3	2 1	2.0	1.9	1.7	1.6	1.5	1.4	1 3	1.2	20
25....	3.1	2.9	2.7	2.5	2 3	2.1	2.0	1.9	1.8	1.6	1.6	1.5	1 3	25
30...	3.3	3.1	2.9	2.7	2.5	2.3	2.2	2 0	1.9	1.8	1.7	1.5	1.4	30
35....	3.5	3 3	3.1	2.9	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.6	1.5	35
40...	3.7	3.4	3 2	3 0	2.7	2.5	2.4	2.2	2.1	2.0	1.9	1.7	1.6	40
45 ..	3.9	3.6	3.4	3.1	2 9	2.6	2.5	2.3	2.2	2.0	1 9	1.8	1.6	45
50 ...	4.0	3.7	3.5	3.3	3.0	2.7	2 6	2.4	2.3	2.1	2.0	1.9	1.7	50
60....	4.3	4.0	3.8	3.5	3.2	2.9	2.8	2.6	2.5	2.3	2.1	2.0	1 8	60
70 ...	4.5	4 2	4.0	3.7	3.4	3.1	2.9	2.7	2.6	2.4	2.3	2.1	1.9	70
80 ..	4.8	4 4	4.2	4.0	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.0	80
90 ..	5.0	4.6	4.4	4.1	3.7	3.4	3.2	3.0	2.9	2.7	2 5	2.3	2.1	90
100	5.2	4.8	4.6	4.2	3.8	3.6	3.4	3.1	3.0	2.7	2 6	2.4	2.2	100
125	5.7	5 2	5.0	4.6	4.2	3.9	3 6	3.4	3.2	3.0	2.8	2 6	2.4	125
150 ...	6.1	5.6	5 3	4.9	4.5	4.1	3.9	3.6	3.4	3.2	3.0	2.8	2.6	150
175 ..	6.4	5.9	5.6	5.2	4.6	4.4	4.2	3.8	3.6	3.4	3.2	3.0	2.7	175
200. ..	6.8	6 3	5.9	5.5	5.0	4.6	4.4	4 0	3.8	3.6	3.4	3.1	2.8	200
250 ..	7.3	6.8	6.4	5.9	5.4	5.0	4.7	4.4	4.2	3.9	3.7	3.4	3.1	250
300 ...	7.9	7.3	6.9	6 4	5 8	5.4	5.1	4.7	4.5	4.1	3 9	3.6	3.3	300
350 ...	8.3	7.7	7.3	6.8	6 1	5.7	5.4	5 0	4.7	4.4	4.2	3.9	3 5	350
400....	8.8	8.1	7.7	7.1	6.5	6.0	5.7	5 2	5.0	4.6	4 4	4.0	3.7	400
500....	9.5	8.8	8.4	7.8	7.0	6.5	6.2	5.7	5.4	5.0	4.7	4.4	4.0	500
600 ..	10.2	9.5	9.0	8.3	7.5	7.0	6.6	6.1	5.8	5.4	5.1	4.7	4 3	600
700 .	10.8	10.0	9.5	8.8	8.0	7.4	7 0	6.5	6.1	5.7	5.4	5.0	4.5	700
800 ...	11.4	10.6	10.0	9.3	8.4	7.8	7.4	6 8	6.5	6 0	5 7	5.3	4.7	800
900...	11.9	11.1	10 5	9.7	8.8	8.1	7 7	7.1	6.7	6 2	5.9	5.5	5 0	900
1,000....	12.4	11.5	10.9	10.1	9.2	8.5	8 0	7.4	7.0	6 5	6.2	5.7	5.2	1,000

velocity much exceeds 15 feet, the bricks of the invert are very apt to be loosened and the whole structure thus put in the way of destruction. At this moment the Camp Spring sewer in St. Louis is undergoing extensive repairs due to this cause. For long sections one or more rings of the bottom brickwork are gone and their place is being supplied by

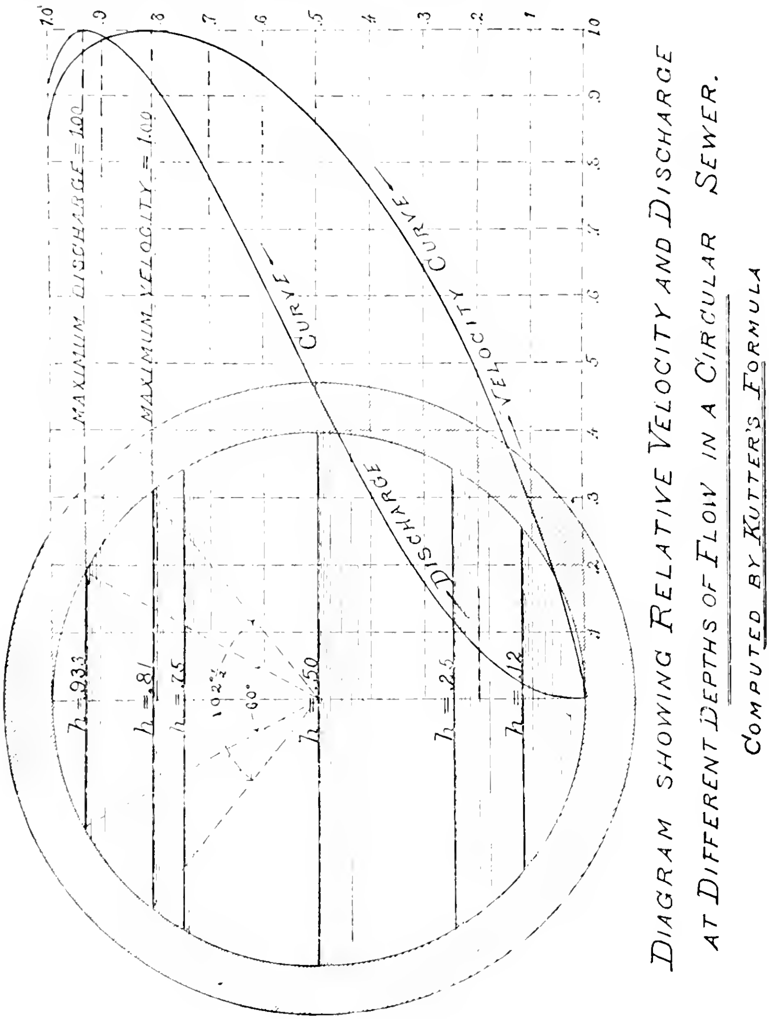


Fig. 4.

an invert made of granite blocks. And numerous other similar instances could be cited. In all these cases, no doubt more careful work in original construction might have preserved the sewers for many years even under the high velocities, but for all this we shall not be far wrong in taking the velocity of 15 feet per second as a danger line beyond which some-

thing more durable than ordinary brickwork is needed in the invert to insure stability.

Second. A curve of velocity of three feet per second at the time of minimum flow, which is assumed to be when the depth of water is one-eighth the diameter and the discharge one-fiftieth of the maximum. This velocity is chosen as about the least that will insure a self-cleansing flow. For velocities less than this, flushing of some sort, either natural or artificial, will be needed unless the water be quite free from sediment. In Table III., the field lying between these two lines is printed in heavy type. Where the values sought lie to the left of this field it indicates that flushing will be needed; where they lie to the right, it indicates that ordinary brick inverts will be in danger, so that to insure permanence either the grade must be lightened or the mode of construction changed.

In this table it will be further noted that the discharge is given in cubic feet per second and not in acres drained, although the latter is sometimes the more convenient unit. The conversion of one into the other is, however, so easy that there seemed to be no reason for abandoning the more generally useful unit, the cubic foot per second.

Inasmuch as one inch of rainfall per hour per acre is almost exactly one cubic foot per second,* we have only to multiply the number of acres to be drained by the number of inches per hour to be discharged to get the number of cubic feet per second. For example, if the number of acres is 100 and number of inches per hour to be discharged is 1.5, we enter the table with 150 cubic feet per second.

Comparing the figures of this table with those of the former table computed by the Weisbach formula for one inch of rainfall per hour, we find the diameters given by the Kutter formula to be considerably the smaller. But as sewers built in conformity to the older table are found by actual experience to be none too large, we have in this fact additional evidence of what is quite clear from other sources, viz.: that in closely built and well-paved cities the sewers are called upon in heavy showers to carry off more than one inch of rain per hour. Just how much this excess is can only be determined by a series of careful observations, of which, unfortunately, the number in this field, as in too many other fields of engineering inquiry, is extremely small.

A DESIGN FOR A STADIA ROD.

By G. A. M. Liljencrantz, Member of the Western Society of Engineers.

[Read June 1, 1886.]

The stadia rod is at this day pretty well known, but I infer, from what I have heard, that there are many surveyors who have not yet learned to appreciate the great value of its use.

I do not pretend to present herewith any new ideas or principles with regard to the theory for stadia measurements. The paper which I sub-

* One inch per acre per hour is $\frac{43560}{12}$ cubic feet per hour, or $\frac{43560}{12 \times 60 \times 60} = \frac{43560}{43200} = 1.0083$ cubic feet per second.

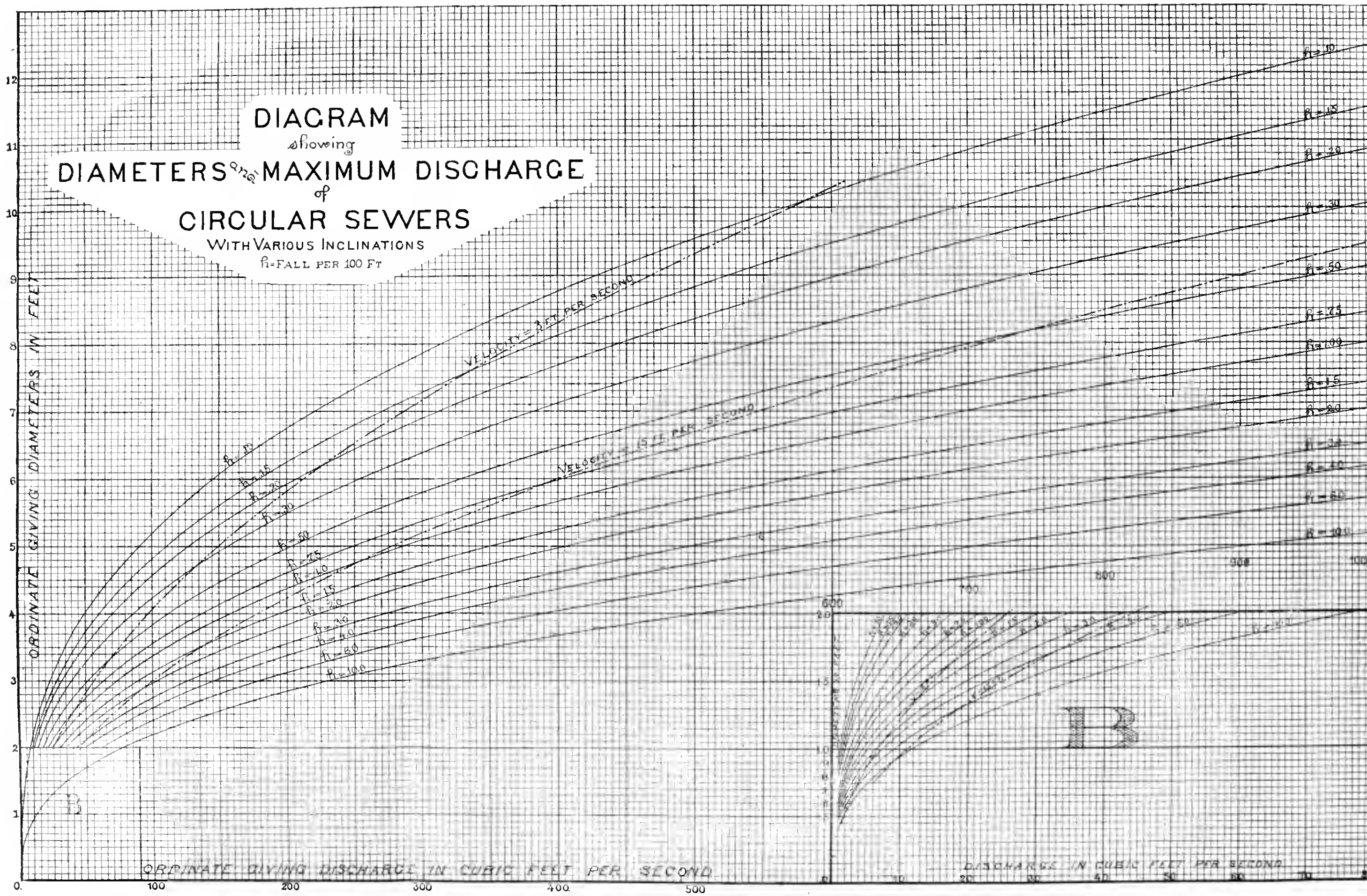


DIAGRAM
showing
DIAMETERS and MAXIMUM DISCHARGE
of
CIRCULAR SEWERS
WITH VARIOUS INCLINATIONS
h=FALL PER 100 FT
ORDINATE GIVING DIAMETERS IN FEET
ORDINATE GIVING DISCHARGE IN CUBIC FEET PER SECOND
DISCHARGE IN CUBIC FEET PER SECOND
VELOCITY = 3 FT PER SECOND
VELOCITY = 1.5 FT PER SECOND
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Figure 5

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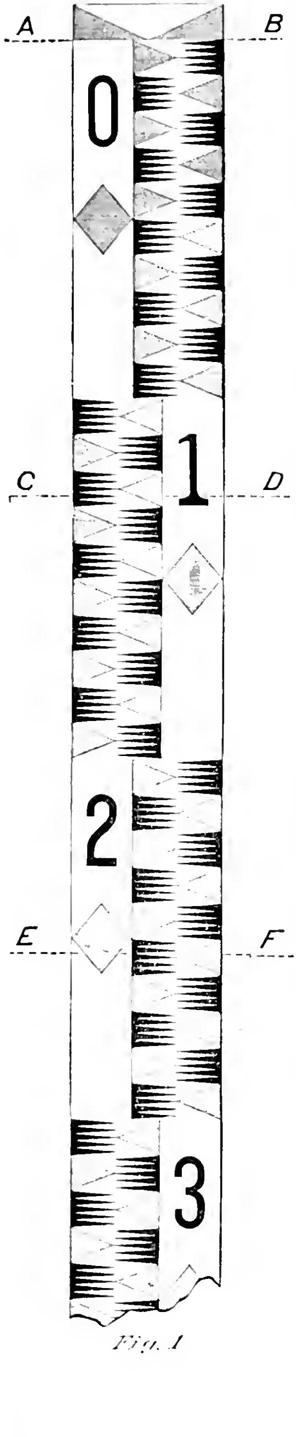

Fig. 1

mit for your consideration is, in fact, not so much a treatise with illustration as an illustration with explanations, for the main point to be here considered is a "design for a stadia rod," which, as I could find no device that appeared to me satisfactory, I constructed in 1881, and the use of which I have found very satisfactory. To the description of this design I have added a few general remarks on the use of the stadia, which it is believed may be of service to those who have not yet used it.

An elaborate paper on the "Stadia and Stadia Measurements" was read before this Society April 2, 1878, by one of its members, Mr. J. C. Roney, who therein treats the subject in a very exhaustive and scientific manner, and those who desire knowledge of the *fine work* which may be done by the aid of the stadia, are referred to that paper.*

For my part, I regard its main value to be found in its use for obtaining, by observation from one established station, the surrounding objects and general topographical features, such as buildings, bridges, fence corners, contours of rivers, groves, etc., in which cases minute accuracy is not required.

To make the stadia most useful, it is essential to have it so constructed that it can be read quickly and correctly; and these qualifications I claim for the one before us.

As before stated, I had been unable to find any existing designs that corresponded to my notions of a desirable construction, the main objections being, that they lacked a sufficiently marked distinction between the various divisions and subdivisions respectively, which would necessarily render the observations more uncertain and unreliable with increasing distance, and cause much loss of time in reading the rod. The chief condition for a quick conception of a large number is to have the divisions and subdivisions distinctly conspicuous, just as a large expression in figures is divided by commas at those indicating thousands, mill-

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* Valuable notes on this subject are also found in the catalogue for 1884 of Heer & Seelig, instrument makers in Chicago.

ions, etc., to facilitate its being read with ease. On that principle this rod was constructed, and its characteristic features may be best explained by a description of its construction. It is made of a board $10\frac{1}{2}$ feet long, 5 inches wide, and about $\frac{5}{8}$ inch in thickness, and is first painted a clear but not glossy white. Ten feet of the whole distance (leaving 3 inches at each end) is divided into equal parts, one foot each in length. Each of these spaces will correspond to a horizontal distance of 100 feet in the field, and is subdivided into 3 perpendicular columns, one of 2 inches in width and the other two of $1\frac{1}{2}$ inches each. The two latter columns contain the 10 subdivisions, each of which represents a 10-foot field-distance; the 2-inch column contains a figure, indicating the number of 100-foot spaces from the initial point to the top of the one in which the figure is found. It also contains a diamond, dividing this space into two halves. To make the 100-foot spaces more conspicuous, the relative positions of the 2-inch columns and those containing the subdivisions are reversed to right and left, alternately in succeeding divisions. The two narrower columns are, as already stated, in their turn, divided into ten equal parts, which are for similar purposes, and in a similar manner reversed alternately in the two columns. The points of the larger angles in the diamond, dividing the 100-foot space into two equal parts, denote the 50-foot distance. The upper angle is opposite the 40-foot mark, and the lower at the 60-foot mark. Thus this diamond furnishes material aid in finding, without loss of time, any of the 10-foot divisions. Each of the outer sides of these last-mentioned divisions is divided into five equal parts, whereby each of these small parts denotes a field distance of 2 feet. On each of these for a base is made an isosceles triangle with its apex on the line between the two columns. Thus the even feet (2, 4, 6, etc.) are found at the blunt angles of these triangles, whereas the apex of each indicates odd feet. Every 5 feet is furthermore marked by the apex of the larger triangle in the adjoining column, made on the 10-foot division for a base. These latter triangles, as well as the diamonds, are on the accompanying drawing represented by shaded surfaces (to facilitate its reproduction in print), but should on the rod be painted a bright red. The space above the graduated portion is by two red triangles so marked as to indicate the initial point or line ($A—B$) from which all measurements are counted, and in using the stadia the upper stadia hair is made to coincide with this line. The lower end of the rod is similarly marked. The initial point has been chosen at the *top*, because in most cases the lower end of the stadia is liable to be obstructed from view by grass, bushes and the like, whereas the top can almost always be seen.

To illustrate the reading of the stadia, an example may be given, which is shown on the drawing. If, when the upper stadia hair has been placed in the position of line $A—B$, the lower one is found in a position like $E—F$, then the distance between these two lines denotes the observed field distance (*minus* a constant, as will be mentioned later on), and is obtained from the position of the lower hair. This we find in the 200-ft. space and two 2-ft. spaces *beyond* the angle of the diamond, indicating 50 ft. Thus the reading is: $200 + 50 + 4 = 254$ ft.

The stadia hairs should always be adjusted so as to be equidistant from the centre hair, and this offers a convenient check for testing the

correctness of the first reading. In observing the position of the centre hair (line $C—D$), we find it in the 100-foot space, *beyond* the second 10-foot space, and two feet *beyond* the 5-foot mark, giving a reading of $100 + 20 + 5 + 2 = 127$, which is one-half of 254, and proves the correctness of that reading. The central position of this hair to the stadia hairs is also very useful for other purposes; for example, if the lower stadia hair should be hidden from view by a branch of a tree or some other object, or if the distance to be ascertained should be greater than that provided for on the rod. In either instance, the desired distance will be obtained by taking twice the distance denoted by the centre hair.

For convenience in carrying and also to protect the painted graduation, the rod should be made in two parts, carefully fastened together by hinges and provided with a suitable clamp-screw arrangement to make it perfectly firm when opened for use.

In the foregoing, it has only been shown how to obtain distances as

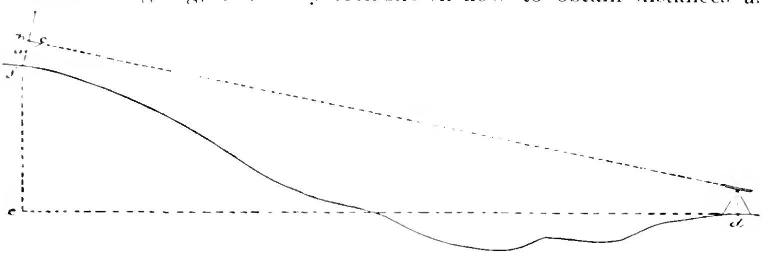


Fig. 2.

indicated on, and secured by the use of, this stadia. Where the surrounding country is practically level and only approximate accuracy is required, the observed readings may be accepted at once, with only the addition *to each reading* of a constant, which is a fixed quantity for each instrument, and ordinarily amounts to something less than a foot. (This constant is the distance between the object-glass and the centre of the axis + the focal length.)

To insure a correct reading, it is of importance to hold the stadia at least approximately at *right angles to the line of sight.* This is easily accomplished by having a right-angled triangle so attached to the stadia that one of its sides, $a—b$ (see Fig. 2) coincides with the side of the stadia and the other, $b—c$, is perpendicular to it, and that the point b is at the same distance from the lower end of the rod as the height of the instrument above the ground. If the rodman sights at the telescope along the side $b\ c$, the object will be accomplished. Where there is a considerable difference in elevation between the relative positions of the instrument and the stadia, as indicated in Fig. 2, the observed distance is, of course, that of the hypothenuse $d—f$. The horizontal distance $d\ e$ is easily found by aid of the vertical angle edf ($ed = df \cos. edf$); but, as stated in the beginning of this paper, such details have been explained by other members, and need not be here further alluded to.

In submitting this device for a stadia, it should be stated that its construction presupposes the use of adjustable stadia hairs, which I regard as preferable. If fixed hairs are used, the divisions on the stadia must be made to correspond, though the principles of sub-divisions, etc., are equally applicable in either case. If the fixed hairs are disturbed or changed, a new rod must be made. Besides, there are other great advantages in having adjustable hairs. If a more accurate reading should be required, as, for instance, to secure for a transit line the distance across a river, creek or other inaccessible place, and to avoid the more inconvenient triangulation, a very good result can be quickly and easily obtained by the use of a leveling rod with two targets, one of which is fixed at the highest point on the rod and the other movable. When the two stadia hairs coincide with the respective targets, the difference between the readings of the latter gives the desired distance (*less* the constant, which should be added). The leveling rod, reading to thousandths of a foot, will thus give a field distance to within a tenth of a foot, which is as close as possibly can be desired. With fixed stadia hairs, the leveling rod could not be so used, unless they should incidentally be so fixed as to correspond to the divisions on that rod.

On one occasion, at the survey of Peoria Lake front, in August, 1883, I used the stadia exclusively, even for measuring the transit line along the shore. It was here found very valuable, as the many buildings and other obstructions close to the water's edge would have made chaining impossible, without numerous and extensive off-sets, which would have tended as much to affect the correctness of the work as the imperfections of the stadia, if not more, and would have required a great deal more time.

Besides having put this stadia rod to practical tests on several of my own surveys, four or five such rods were made for, and used by, the engineers of the different parties of the Hennepin Canal surveys in 1882, and were by them said to be easily understood and read, and to give very satisfactory results.

EDWARD B. TALCOTT.

A MEMOIR.

By Willard S. Pope, Member of the Western Society of Engineers.

[Read April 6, 1886.]

Edward B. Talcott was born in Rome, N. Y., in April, 1812. He had in his youth the advantages of as good an education as the common school and academy of that day and place afforded. In 1835 his father moved to the then remote Chicago, accompanied by his two sons, Edward B. and Mancel. Mancel Talcott subsequently was of the firm of Singer & Talcott, proprietors of one of the large stone quarries at Lemont, near Chicago. Edward B. entered the employment of the Illinois and Michigan Canal as engineer, in which capacity he served many years. He left this service once to become Deputy United States Marshal for the Northern District of Illinois, and again to become City Surveyor of Chicago, but in each case returned again to the charge of the Illinois and Michigan

Canal. About 1855 he became connected with the Hannibal & St. Joseph Railroad, then being constructed. He had special charge of its Land Department, and in addition performed effective service in the building of the road. In 1860 he was appointed General Superintendent of the Galena & Chicago Union Railroad Co., in which capacity he served until the consolidation of that railroad with the Chicago & Northwestern in 1864, after which, until 1866, he acted as Chief Engineer of the consolidated lines. In 1867 he connected himself with a company which undertook, as contractors, the construction of the Grand Rapids & Indiana Railroad in Michigan. He had full charge of all the active operations in the field. In 1873 he experienced a slight attack of paralysis, from the effects of which he never entirely recovered. His life-work was done and from that time he was more or less an invalid, until his death, which occurred in February, 1886, at the age of 74 years.

As an engineer his work was extensive and varied. Canal and railroad construction, land drainage, surveying and platting, dock and bridge building—in fact, all the details of construction that a new and rapidly growing country demands—with all he was familiar ; in all expert. His intuitions were quick and his judgments were sound. He eminently possessed that faculty, without which education is vain and training idle, viz.: good, practical common sense.

His life was spent in a new country where great results had to be accomplished with limited resources, and his constant thought and study was necessarily for economy—to attain the desired end with the least possible cost. In the public works over which he had charge, nothing was expended for mere ornament or show ; but no one was more scrupulous than he in the effort to build solidly and well. He never allowed work to be "scamped ;" though compelled sometimes by a lean purse to use makeshifts and temporary expedients, he always did so reluctantly, and got rid of them as soon as possible thereafter. I remember how persistently he urged on his rather slow and conservative board of directors of the Galena Railroad the adoption of iron and stone in place of wood for bridges. That company was among the earliest in the West to introduce iron structures ; the bridge over Fox River near Elgin, on that road, built in 1860, being, I think, the first iron railroad bridge west of Chicago ; and it was mainly due to his persistent effort that the company was induced to try what they seemed to consider a rather expensive experiment. During his superintendency many of the wooden structures on that road were replaced by substantial stone arches and iron spans. Railroad companies now regard such permanent renewals as a matter of course; but those days were very different ; and among the great achievements of the present, we should not forget the struggles of our professional fathers. It required a good deal of nerve and self-confidence then to advocate and attempt constructions which now are simple matters of course.

The principal single engineering work constructed by the Galena Railroad Company during Mr. Talcott's superintendency was the bridge over the main channel of the Mississippi River, at Clinton, Iowa, in 1863. It was a difficult place—a channel about 800 feet wide, a depth of water of 45 feet at low stage and 65 feet at high stage, a considerable current, a

bottom of loose, light sand, about 15 feet in depth, overlying bed rock of limestone. In extreme floods the rock was sometimes possibly laid bare. It was necessary to place one pier in mid-channel large enough to carry a drawbridge 300 feet long, which when open would leave a clear waterway of 120 feet on each side for navigation. When the span was open it must be protected against collision from boats for its entire length up and down stream. At the present day it is easy by the pneumatic system to place stone piers directly on the bed rock; but this was 23 years ago, and the methods of submarine founding had not then reached their present advanced development. The case received much anxious consideration and study.

Mr. Talcott finally decided to found the pier as follows: A timber crib was built 400 feet long, 45 feet wide and 45 feet high. The central part was divided into compartments 5 feet square, and the ends into compartments 10 feet square. This was floated into place and sunk, and the compartments filled with rubble stone. The bottom bedded itself into the sand and the top was just below low water line. On this the stone pier was built. The crib was a ponderous mass to handle in the strong current and against the cross eddies. But when once fairly landed it formed a solid and reliable foundation, and the years that have since passed have proved the sound judgment of the engineer. Of course, by reason of his multifarious other duties, Mr. Talcott was not able to devote much personal attention to the details of this work, which for that day was a great one. But he took a constant, hearty interest in it, received daily reports of its progress, and his orders decided all important questions.

In this, as in all other work in which he was engaged, he drew about him a corps of subordinates and assistants, all of whom became sincerely attached to him. Rigid in the performance of duty himself, he was strict and even sometimes apparently severe in demanding full duty of others. But his severity was always simple justice, and was so tempered with kindness that no one could complain. Sternly impatient of laziness and incompetence, he was fully appreciative of zeal and energy in his staff of assistants; and beneath his bluff, quick manner, lay always a kind heart. Many a man now prominent in the various departments of railroad service looks back to the days of his early work with feelings of gratitude and affection toward his old chief, E. B. Talcott.

In person, Mr. Talcott was tall, well formed and vigorous. His features were sharp cut and striking, his hair curling, and the glance of his clear blue eye keen and incisive. He bore the stamp of leadership upon him. The tones of his voice conveyed irresistibly the impression that he meant what he said, and when he gave an order there was no doubt or hesitation in anybody's mind about obeying it. The action of both his mind and his body was quick and energetic; there was no wavering or vacillation about him. He was a great worker, incessant and indefatigable; and when at work his whole heart was in it; so that he often seemed hasty and impatient of interruption; and to those who saw him only at such a moment he might perhaps appear unnecessarily curt and irritable. But when freed from the immediate press of thought or occupation, his whole nature was as kindly and genial as sunlight. He was a man of strong and enduring affections; and to his friends—and they were many—his

heart and his hand were always open. He was a member of our Society from the beginning; always interested in it and in its members. Of late years, since his illness, his life has been quiet, and we have not seen as much of him as before. Possibly to some of our younger members he may have been personally unknown; but all the older ones well remember his tall, spare, slightly stooping figure, his kindly face and his cordial manner; and in his death we feel that the Society has lost an honored member, and we a valued friend. He was a good man. May he rest in peace!

In looking back over his busy life, we see much to admire and to imitate. Let us draw also one lesson of what to avoid, and that is, briefly, too incessant application to work. Our friend fell with the full harness upon him, stricken down in a moment, in the very field of his usefulness, and in what ought to have been the real prime of his life. He had warning enough and advice enough, as we all of us have already had who have reached middle life; but he couldn't give up just then; wait a little while, until business was less pressing, then he would take the needed rest and holiday. And so he pushed on, every muscle tense, every nerve strained, every faculty alert, until suddenly the bolt fell—a shock of paralysis, and his business was terminated. Although he lived 13 years afterward, yet it was a hampered and a crippled life; his mind as eager and as bright as before, but his body frail, shaken and unable to respond. How many of us are traveling the same path!

NOTES ON THE PANAMA CANAL.

By Charles D. Jameson, Member of the Boston Society of Civil Engineers.

[Read May 19, 1886.]

The idea of connecting the Atlantic and Pacific oceans by means of a ship canal across the isthmus between North and South America was almost contemporaneous with the discovery and conquest of the country by the Spaniards.

The first paper upon that subject was written in the year 1550, and in this paper the relative values of the Nicaragua and Panama routes were discussed.

The next notice we have of the idea was in 1779, and surveys were ordered by the Spanish Government in 1780. But owing to complications in Europe, these surveys were not made, and none of these earlier Spanish projects ever advanced far enough to have any reliable surveys or plans made.

When, in 1825, the most of Central America had thrown off the Spanish yoke, and had become small, independent republics, they, knowing so well the configuration of the coast, and the feasibility and advantages of a ship canal, did all in their power to have the question well studied and brought before the notice of the world.

In 1825 the Republic of Nicaragua asked the co-operation of the

United States in the building of a ship canal connecting the Atlantic and Pacific oceans. But as the United States Government could at that time get hold of no reliable data connected with the subject, it was no deemed advisable to commit the Government to any such grand undertaking. The only result was that a new minister was sent to Nicaragua with instructions to examine into the question fully and collect all possible data.

The first regular survey of a line across the Isthmus of Panama was made at the expense of the Government of New Grenada in 1828, from the mouth of the Chagres River to Panama. This place at that time was considered one of the most feasible places for cutting the isthmus, as it was one of the narrowest, and also there is a great depression in the main chain of mountains.

There was really very little reliable work done on the isthmus in the way of any surveys for a canal until 1870, and from then up to 1880 all the best work was done by the United States Government. The principal attention of this Government has always been turned toward the Nicaragua route, although there have been eleven different routes surveyed and plans and estimates made.

Owing to the fact the Nicaragua route is in a more inhabited and healthy climate than any of the others, and also that the estimated cost of construction has always been less, this route has always been the one most advocated by our Government.

We will now look at the manner in which the French came to have the concession for, and the control of the Panama canal.

While the United States Government was having careful surveys and estimates made of all these different lines, a lieutenant in the French navy named Lucien Napoleon Bonaparte Wyse, and Lieut. Armand Reclus, with a party of about twenty men, in 1876 commenced an examination of some of the lines which had been run across the isthmus. These exploring parties under Wyse and Reclus spent the better part of two years on the isthmus in examining into the different merits of the many lines which had been run, and also to decide as to the actual feasibility of building a canal at all.

The expenses of these exploring parties were defrayed by a private company in Paris. As soon as Lieutenant Wyse had procured all the information and data he required, or at any rate had used up all the time at his disposal, he pushed on at once to Bogata, the capital of the United States of Colombia, and on March 28, 1878, got his concession signed by the Government.

By the terms of this concession he was granted the exclusive privilege of constructing a ship canal from Colon to Panama for a period of ninety-nine years ; the canal to be finished in 12 years after the organization of the company, and if any unforeseen obstacles are encountered, the limit of time for construction will be extended six years more. There can be no doubt but that the Canal Company have a right to this additional six years, as most of the obstacles which they have encountered appear to have been entirely unforeseen.

Lieutenant Wyse then went at once to New York to see what arrangements could be made with the Panama Railroad, as it was then evident

that the best line between Colon and Panama must run near the line of the railway, or at least within their right of way, and that the co-operation of the railway company would be all-important to the construction of the canal.

Having made his arrangements in New York, he sailed at once for France. Now, this company of which Wyse was the head had a concession and all the rights necessary for the construction of an inter-oceanic canal across the Isthmus of Panama; and the only and by far the most important thing which they lacked was the necessary amount of money.

In order to form a company and raise the immense amount of money necessary for the undertaking, it needed, as the head and front of the enterprise, a man the simple name of whom could so inspire and rouse the people that without knowing much more about the enterprise than the one fact that this man was at the head of it, would give them un-

bounded confidence in its success and the enterprise unlimited credit. The only man who could fill these requirements was Ferdinand de Lesseps, who, with his fame founded upon the construction and success of the Suez Canal, could raise money to any amount for any enterprise to which he lent his name.

Le comte de Lesseps was induced to become the head of the Wyse-Reclus canal project, and a scientific congress of all nations was called at Paris to decide as to which of the many lines run across the isthmus was the best. The decision of this congress was in favor of a sea level canal from Colon to Panama. This decision was rather a foregone conclusion, from the fact that the Colon and Panama route was the only one of which Wyse held the concession and of which De Lesseps was the head. Unless one has been in France, and particularly in Paris, they can form no idea of the amount of influence and blind enthusiasm the mere name and reputation of one man can arouse. De Lesseps made a success of the Suez Canal in the face of the strongest opposition, and to the ordinary French people he is little less than a God. The majority of them are satisfied with the fact that he says the Panama Canal will be a success, and up to the present time he has merely had to ask for money to get all

and more than he asked for. In June of 1884, when he called for 80 millions, the morning when the books were opened to receive subscriptions, the streets were packed for blocks with people who took their luncheon and crowded and pushed all day to get a chance to let *him* have all their savings. The money which has thus far been spent upon the Panama Canal has not come from rich bankers and capitalists, but in small lots out of the pockets of women and orphans and the middle class of French people, who seem willing to pour into the capacious pockets of De Lesseps their last cent, and take his word for it that at some time in the future they will reap their reward. Perhaps they may. Where the remainder of the money needed to finish the Panama Canal is to come from is a query.

We will now leave le comte de Lesseps and his poor people in France and go to the Isthmus of Panama. The administration of the Canal Company upon the Isthmus is as follows: Director-General, Assistant Director-General, Chief Secretary, Chief Engineer, and a great number of other chiefs up to about 700. In fact, nine out of ten of the employés of the Canal Company are chiefs of something, and a man must indeed be down pretty low not to be able to write chief after his name. During the five years of construction upon the Isthmus there have been eight different administrations, no one of them lasting two years. Of course, this has been a source of great loss to the Canal Company which can hardly be exaggerated.

The Panama Canal is to be a sea-level canal from Colon on the Atlantic side to the mouth of the Rio Grande, on the Pacific side near Panama. The total length will be 74 kilometers, or about 45 miles. At the Pacific end there will be a tide-gate by which to control the excess of tide of the Pacific Ocean over that of the Atlantic. The difference between high and low tide in the Atlantic at Colon is only about 12 inches, while in the Pacific it is 20 or more feet.

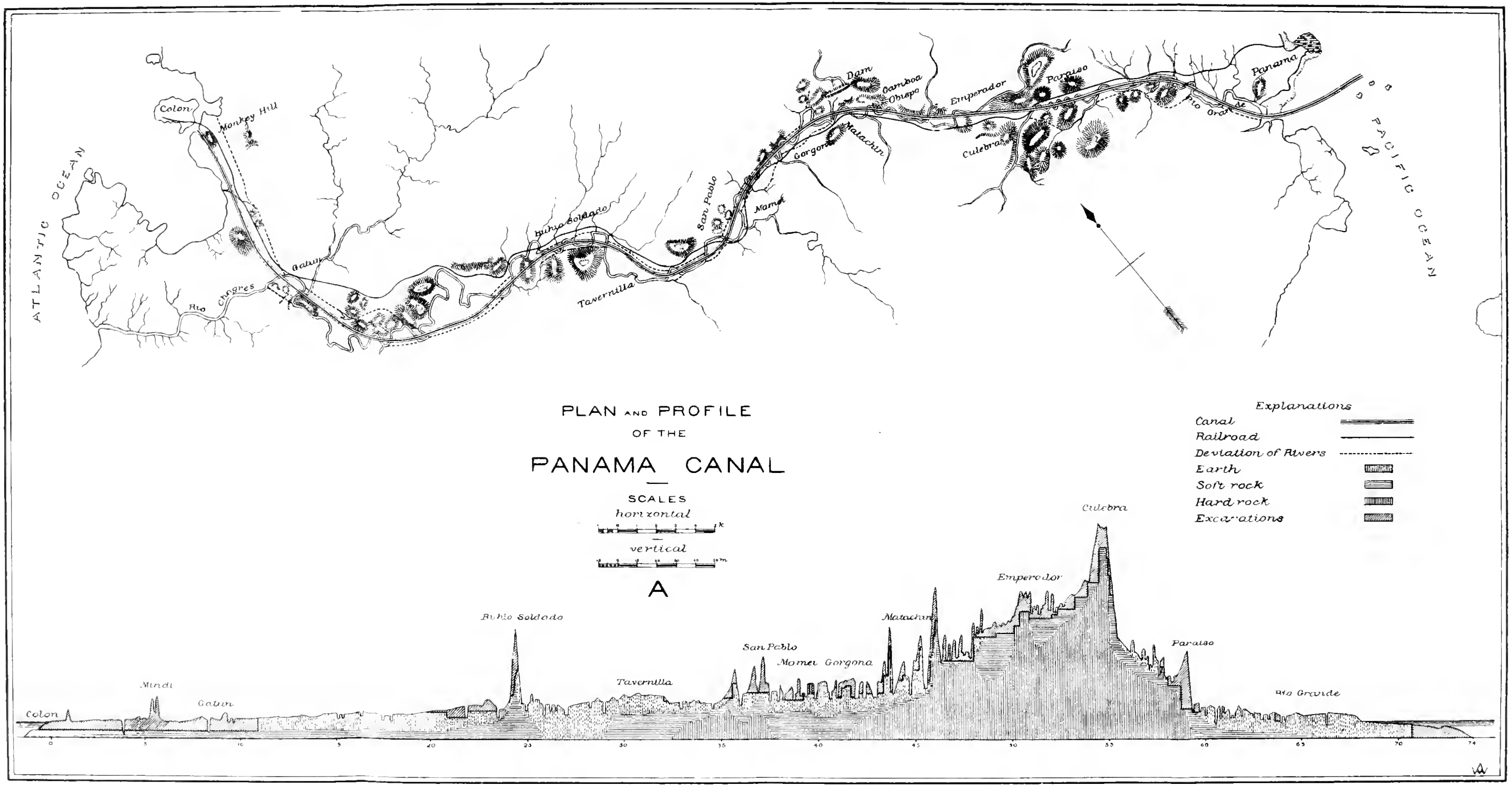
At the Panama end there will be a basin 1,600 metres long and 110 metres wide. At Traverulla, at about the centre of the canal, there will be a large basin about 5 kilometers long, and at Colon there will be a basin well protected by a sea-wall—a basin 3 kilometers long and 1 kilometer wide.

The bottom of the canal will be 30 ft. below the water line and will be from 100 to 200 ft. wide. The deepest cut upon the centre line is at kil. 55 Culebra, where it is 330 ft. for a short distance, at this point the depth of cutting at the slope stakes runs up to 450 feet.

By means of the profile one can form some idea of the comparative quantities of each kind of material to be excavated. The whole line of the canal has been sounded to its full depth by means of the diamond drill and the cores of the entire soundings extracted and classified.

The City of Colon (Aspinwall) is situated upon an island upon the Atlantic side of the Isthmus of Panama, and the whole of this island is owned and occupied by the Panama Railway, who will not sell one foot of it. The city itself consists of only two streets running parallel to the water, and which before the fire of March 31, 1885, were lined with stores, bars and tenement houses.

There is no drainage of any description, and refuse of every kind is



PLAN AND PROFILE
OF THE
PANAMA CANAL
SCALES
horizontal
vertical
A
Explanations
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Railroad
Deviation of Rivers
Earth
Soft rock
Hard rock
Excavations
ATLANTIC OCEAN
PACIFIC OCEAN
Colon
Monkey Hill
Gatun
Rio Chagres
Bohio Soldado
Tavernilla
San Pablo
Mamei
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thrown into the streets, which with the vacant lots are gigantic cess-pools. You hear a great deal about the deadly climate of the Isthmus, and beyond a doubt it is unhealthy. But if the people here in Boston lived in so much filth and drank as much brandy, the death-rate would be nearly as great

When the Canal Company wished to build their offices, store-houses and dwelling houses at that end of the canal, there was no land available where they could build a line of wharf which would be accessible to vessels of all kinds. So to the south of the island, as you will see by the plan *B*, they took a large swamp which was usually under six feet of water, and filled it with broken stone and gravel to about six feet above high tide: on the top is put 18 inches of rotten coral to give it surface. This rotten coral packs down very firmly and is entirely free from dirt and dust. This whole fill contains about 85 acres.

Upon one side of the fill, as shown on the plan, there is nearly one mile of stone wharf, with about 25 feet of water. Upon this fill are built all the dwelling houses, offices, store-houses, etc., of the canal company.

That part where the dwelling houses are built is laid off well in streets, and is well drained. There are sidewalks and cut stone gutters. All the buildings are built upon masonry pillars a few feet high, in order to allow the air to circulate freely under them.

The whole camp is in charge of a special police force whose only duty is to keep it clean and orderly.

Owing to the fact that all the freighting is done by cars and locomotives, it is very seldom that the streets of this encampment are desecrated by the presence of any beasts of burden or that the streets are cut up by wagon wheels. Therefore, the camp can be and is kept most exquisitely neat and clean, and no expense is spared to accomplish this object.

Much of this care and expense, which is lavished not only upon the camp at Colon, but upon the camp of each section along the whole line of the canal, strikes the American who is new to the country and climate as a great waste of money. But after a little examination into the beneficial results arising from this same expense, any one will admit that it is perfectly justfiable. You all know by the newspapers what a tremendous death rate prevails in Aspinwall, but at the canal camp, which is merely one part of it, from June, 1884, to June, 1885, there were only four deaths, with a population of six hundred, and two of these were the direct result of intemperance. With all the sins of omission and commission of the Canal Company, and they are many, one must admit that in regard to the care taken of the health of their employés, in their commissary, sanitary and medical departments very little can be found lacking.

The large hospitals of the Canal Company were built at an immense cost, at a few miles from Panama and 200 feet above the sea. The position was most admirably chosen, as there is always a good s a breeze, and the drainage is perfect. The capacity of this main hospital is about 400 beds, and all the arrangements for the comfort and care of the invalids are made in the most perfect manner. There is a smaller hospital of 100 beds at Colon, and a fine sanitarium upon the Island of Taboga,

where the employés are sent for a change of air when necessary. All the employés of the Canal Company are admitted to these hospitals, and receive the best of care, food and room free of charge. The only thing needed is a doctor's certificate that he is sick. Any men working for contractors are admitted to the general wards for $1 per day, which includes everything, and those who wish it can have a private room for $1 extra. When the price of table board, and not very good board either, is from $50 to $100 per month all over the Isthmus, one can see that these hospitals are an immense expense to the Canal Company, and that they spare nothing which in any way tends toward the good health of their employés.

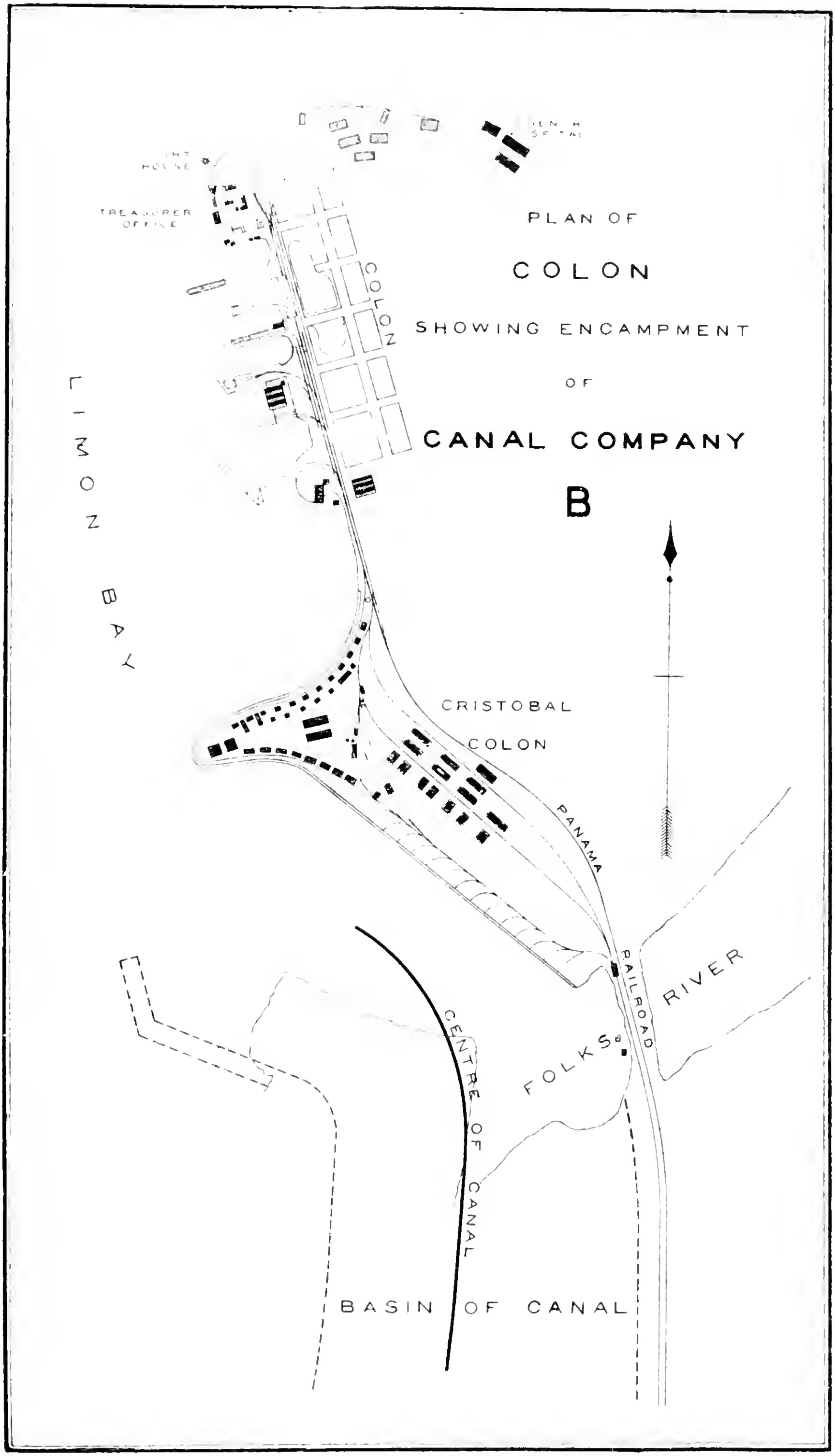
However well disposed one may feel toward the Canal Company, no one can deny that the management on the Isthmus has been very loose and very badly directed, and that a tremendous amount of money has been spent for which no result can be shown. The most noticeable thing about the employés of the canal (with one or two rare exceptions) is that none of them feel any interest in the success of the enterprise. Every man is working for himself and seems to care very little what progress is made so long as he draws his salary regularly once a month. There is none of that holding a man down to his work and either making him do it or getting some one in his place at once who will do it, that we see among the Americans.

Owing to the unhealthiness of the climate and the consequent uncertainty of life, the one idea on the Isthmus seems to be, get what you can, how you can, as quick as you can, and get out of the country. The main offices of the Canal Company are in Panama, in one large building which contains during working hours between four and five hundred employés. The salary of the Director-General is $100,000 per year and all his expenses, including house, horses, carriages, servants, etc.; in fact, everything he can possibly want.

With the exceptions of some six or eight persons holding the most important positions, and whose salaries range from $10,000 to $25,000 per year, the salaries paid by the Canal Company are not by any means high, considering the country and the prevailing rates of wages for the same class of services by the other companies, such as the Panama Railroad and the Pacific Mail Steamship Company.

The line of the canal is divided into sections of about six miles each. Each of these is in charge of an engineer. He has a first assistant, clerk, draughtsman, instrument men, time-keepers, store-keepers, doctors, etc. The salary of a chief of section is $200 or $250 per month and his board; assistant chiefs, $150, and instrument men and draughtsmen from $60 to $100 per month. A chief of section was allowed $2 per day for expenses, and below him about $1.50 per day, varying, of course, with circumstances.

At the headquarters of each section there are comfortable and airy houses sufficient for the accommodation of all the employés above the rank of laborer, and large barracks for the laborers. All these section camps are well policed, have a capable doctor and a small hospital. These section hospitals are merely to be used in case of accident or in very mild cases. In other cases, the patient is sent at once to either Panama or Colon.


PLAN OF
COLON
SHOWING ENCAMPMENT
OF
CANAL COMPANY
B
HOUSE
TREASURER
OFFICE
COLON
LIMON
BAY
CRISTOBAL
COLON
PANAMA
RAILROAD
RIVER
FOLKS
CENTRE OF CANAL
BASIN OF CANAL

To make it an object to the employés to stay on the Isthmus and continue in the employ of the Canal Company, the following inducement is offered: When any one has been in their employ two consecutive years, he is entitled to six months' vacation, with full pay and his fare paid to any part of the world and return. Very few, however, have been entitled to this vacation, and it has been found that of those few the majority preferred to continue with their work and have six months' extra pay and $200 for expenses put to their credit.

Of course, the climate of the Isthmus, like all tropical climates near the sea level, is most unhealthy. The prevalent diseases are dysentery, malarial fever and yellow fever, and when one is taken down, the most powerful remedies must be used at once or it will be too late. This climate, doing away with the fact of its unhealthiness, is one of the most beautiful in the world, but not the most invigorating. The nights are all cool enough to sleep well, and in the shade the heat is never oppressive in the day-time.

We will now take a look at the class of men who are doing all this work on the Isthmus.

Most of the higher positions are filled by Frenchmen, but the Chief Secretary, who is one of the hardest and best workers on the Isthmus, is an Englishman, Colonel Chamberlain, of the English army.

The chiefs of section are all French, and the clerks, under-secretaries, storekeepers, etc., are mostly Jamaica or Martinique negroes who have a fair common school education.

The laborers are in about the following proportions:

Greeks and Italians	.10
English, Americans and Swedes	.06
Germans	.04
Columbians	.20
Jamaica and Martinique negroes	.60
	1.00

Among these the Greeks are by far the best and most intelligent workers, but much care must be taken not to work them in mixed gangs, but in gangs by themselves, as they are a vindictive, quarrelsome set, and very ready to use a knife. Being much addicted to drinking and gambling, they cannot be in any way depended upon.

The Swedes are about the best workers where only a moderate amount of intelligence is needed. The are very faithful, but also very stupid. The English and Americans whom one sees on the Isthmus as laborers are the very scum of the earth. The most of them are runaway sailors who are tempted by the larger pay. As a general rule, the English and Americans of the laboring class upon the Isthmus are divided into two classes. Either they are killing themselves with drink and are therefore of no use, or else they are such fools as to be absolutely useless.

The native Colombians are of Indian blood or Spanish and Indian mixed. They are a straight, well-built race, but owing to the climate and the very little need there is for work in order to live, they are a lazy, indolent set, who make the women do most of the work, and whose only desire seems to be plenty of sleep, bananas, cigarettes and brandy. Consequently, they cannot in any way be depended upon by either the Canal Company or the contractors, and until the last year they have been so much taken up with revolutions that they have cared little whether

they worked or not. The only kind of work for which they have shown any adaptability is the clearing of the "right of way," and most of this work has been done by them.

In this question of the supply of the manual labor needed, which, without doubt, is the gravest one the Canal Company have to face, the Jamaico negro seems to be the only answer so far, that has any degree of stability to it. They form the main body of the laborers upon the Isthmus, not because they are even as good workers as many other nationalities, but because there are more of them. They are mostly imported directly from the islands at the rate of about 1,000 per month under contract for two months at $1.50 per day.

There are no Chinese employed as laborers on the canal, but at every encampment you will find them as small merchants, and in the city of Panama there are several large mercantile Chinese houses. During the construction of the Panama Railway, and once since, that company and the Pacific Mail Steamship Company have imported large quantities of Chinese as stevedores and laborers, but each time they have been a failure, and the companies have had to fall back upon Jamaica negroes. The laborers work from 7 to 11 A. M. and from 2 to 6 P. M.

The clerks and office men work from 8:00 to 11:00 A. M. and from 2:00 to 5:00 P. M. No employé of the Canal Company ever by any accident overruns these hours. There is no night work done, and no Sunday work.

Most of the actual work which has been done upon the line of the canal has been done by contract, and in all of these contracts, with the exception of two, of which I will speak later, the tools and all the necessary machinery were furnished by the Canal Company. The contractor is obliged to give bonds for only 10 per cent. of the amount of his contract, and to pay 7 per cent. of the cost of the tools for their use.

During the last three years the great object of the administration on the Isthmus has been to make a showing in the amount of material excavated, and therefore any one who could give any bond at all and would agree to commence work at once and push it, could make his own conditions with the Canal Company. For this reason all the large contracts which had been made up to one year ago were all in favor of the contractor, and any of them who lost any money on them must indeed have been stupid.

In these contracts, where the Canal Company furnished all the tools and machinery, any delay caused the contractor by the non-delivery of the tools on time is so much more time allowed to the contractor in which to finish his work, and any expense caused the contractor by the non-delivery of the tools, etc., such as large gangs of men, locomotives and excavators standing idle, must all be paid for by the Canal Company. The service of the store-houses being organized in nothing but an immense amount of "red tape," a judicious contractor usually had a monthly estimate of damages due him two or three times as large as the amount due him for actual work done. In this way contracts could be taken at a very low figure and still prove a source of profit to the contractor.

To illustrate his point more fully, I will give you the actual figures on one of the largest contracts which has been let on the Isthmus. The con-

tract price per cubic metre for material excavated we will call 3 cts. At the end of one year's work, taking the total amount of money which had been paid this firm for work done and demurrage on the machines, when standing idle at expense of the Canal Company, and dividing this amount by the actual number of cubic metres excavated, the cost to the Canal Company per cubic metre was 17 cts. in the place of 3 cts., as per contract.

This is rather an extreme case, but those are the actual proportions. You can, therefore, see at once the fallacy of any estimate of the cost of completion based upon the contract prices, and it is upon these prices that the estimates of cost have been based by the canal authorities.

All the large contracts are divided into sub-contracts where possible. No contractor, when it can possibly be avoided, ever works any men by the day, but all by task work. But the large gangs of laborers who work directly for the Canal Company are working by the day. That is, putting in so many hours per day on the work for which they are paid.

Common labor receives from \$1.50 to \$3.00 per day, and skilled labor, as machinists and boiler makers, \$5.00 to \$10.00 per day.

All the laborers receive their pay every two weeks. Office men receive theirs once a month, and contractors receive theirs once a month or as per terms of their contract.

The main storehouses of the canal are at Colon, but at each section camp there is a large one well stocked, and also some large ones in Panama. These store-houses are packed with everything one can imagine, and most of the articles in the most ridiculous quantities. For example, they unloaded and packed away in Colon, in one place at the same time, 600 anchors all of the same size and make.

Each of these store-houses is in charge of a chief and a number of assistants, who report to the Chief General of the Store-houses and Material. But if you wish for anything in a hurry, the only way to get it is to hunt round till you find which store-house it is in, and then, getting an order from the Director General of the canal for it, go and get it yourself.

MACHINERY.

For all the train work which is done on the main line of the Panama Railroad, American locomotives and American or English drivers are used entirely, but for all canal work in their own yards and cuttings, a small French or Belgian locomotive is used.

The dump cars used in the excavation are of English, American and French make. In opening all the works, small hand cars are used until there is a sufficient face on the work to admit the use of the steam excavator or the steam shovel.

The steam shovel used the most and the one which gives the best satisfaction is the Osgood & McNaughton, Albany, N. Y.

One of the best working excavators used is of French make. It consists of an endless chain of buckets, which works either at right angles to the track upon which the excavator stands or in the same direction. The ladder around which the buckets revolve can be raised or lowered at the bottom so as to feed the buckets, and the excavated material is dumped into a hopper about 20 feet high, from which it falls into a dump car which runs upon a parallel track. The motive power is con-

nected to the buckets by means of a flat chain running over a toothed wheel.

The company have on hand pumps of most every description and size, and miles of large, heavy piping which they propose to use in the following manner. Of course one of the gravest questions to be answered in connection with the construction of the canal is, what is the cheapest and best way to dispose of the material which will come out of the large cuts in the interior? There is very little chance for spoil banks without crossing the mountains into the next valley, and the length of haul stretching out into miles. Now the design, and to a certain extent the practice, is to dump all this material into large tanks placed in convenient positions and partly filled with water. These tanks contain agitators which reduce the whole to a semi-fluid state, and then the large force pumps, force it all through these miles of pipes to the most convenient dumping ground. At every section camp where any work of construction is going on, there is a machine shop of greater or less extent. The main machine shops are at Gorgona, and are well fitted up in every detail. One reads a great deal in American newspapers about the immense quantities of machinery which have been allowed to rust away to ruin. This most certainly is an exaggeration. Of course, some machinery imported has been ruined by rust, but only a very small per cent. The rest of it is all taken good care of and kept in working condition.

FLOATING MATERIAL.

This includes in Colon a row-boat, with an awning and from one to eight oarsmen for each chief, assistant chief, head clerk, clerk, etc. As a man's position is, so is the number of his boatmen.

There are two small steam launches and eighteen tow-boats, all of them very small except six. All these boats are of metal and English build. There are six large steam hopper barges (clapet), also English build. These barges and tow-boats are mostly manned by Greeks, who are the best sailors and pilots to be found in that part of the world.

All the dredges used on the Atlantic end of the canal work a number of buckets upon an endless chain. There are three classes of these dredges:

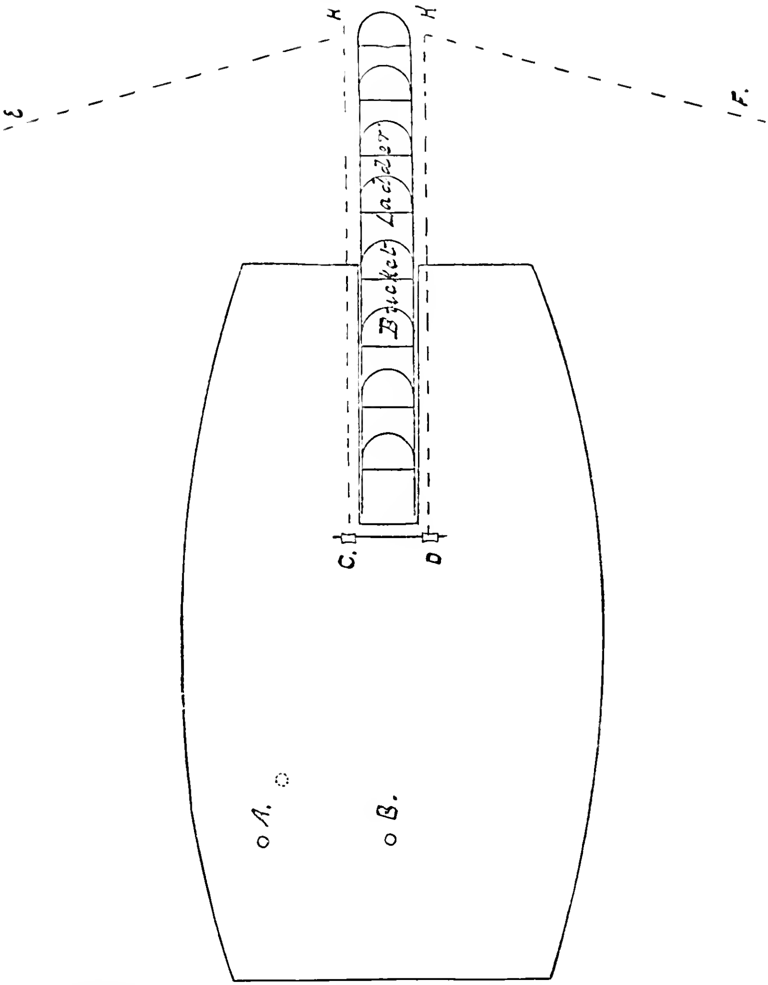
1st. Small French dredge.

2d. English marine dredge.

3d. American dredge, Hercules type,

The French dredge is a small dredge, with the bucket ladder projecting in front so that it can dig its way into banks and thus float itself. One drawback to it is that it has to be held to its work and moved bodily from side to side and ahead by means of chains and anchors run out ahead and on each side. The buckets empty into a hopper 25 feet from the water, and the material falls at once into a scow moored alongside for the purpose, and which, when full, must be removed by a towboat and another put in its place. The capacity of these dredges is about 800 cubic metres in good material per day. The English marine dredge is built all of steel and can dig 40 feet deep. They cost the Canal Company $200,000 each. They have only two of them, one at Colon and one at Panama. They both came from England under steam alone.

They can only be used in deepening channels, etc., as they only work under themselves and must always have enough water to float them. They also discharge all the dredged material into scows or clapets. The power in both the marine dredge and the small French dredge is carried from the main engine to the shaft, which works the buckets by means of a flat chain running over toothed wheels.



The capacity of the marine dredge is about 1,000 cubic metres per day.

The American dredges are built and owned by the "American Contracting and Dredging Company" of New York, and I will here say that this company and the Franco-American Trading Company, which as yet has done no work to speak of, are the only contractors on the Isthmus who furnish their own machines, and also that up to date the American

Contracting and Dredging Company are the only contractors who have made any headway in their work, or have complied with their contract as to time. At the rate at which they are now working there is no doubt but that all their contract will be finished well within the required time.

The main differences between the American dredges and those already named is: 1st. Their immense size, the tower upon them being 75 feet high. They were built expressly for the Panama Canal, and dig 50 metres wide by 10 metres deep. 2d. They possess the following great advantages :—

All the material which they dredge is discharged at once upon the bank through a pipe 36 inches diameter and 150 feet long, and thus they do away with the use of all scows and tow-boats. In the last dredge built by this company, "The New York," there is a discharge upon each side of the tower 170 feet long. There is enough water forced through these discharge pipes to force all the material dredged through them at a velocity of 500 feet per second.

The second great advantage which these dredges have is the manner in which they are made to walk themselves right up to their work, and thus do away with the anchors and chains in front, and to each side. The cut on the preceding page is a sketch of the working deck of one of these dredges.

Twenty feet from the stern of the dredge are two upright, 20-inch round timbers, 70 feet long, and pointed and shod at the lower end. These two timbers pass directly through the bottom of the dredge at the points *A* and *B*. *H K* is the end of the bucket ladder, and the dotted lines *C K F* and *D H E* are lines passing through snatch blocks at *K* and *H*, and fastened to trees at *E* and *F* upon the shore, and running inboard and around gypsy heads at *D* and *C*. When the dredge is at work the centre timber, or, as it is called, spud *B*, is down, and holds the dredge firmly from backing, and by taking in on *D* and *C* alternately, the buckets are moved from side to side of the canal, cutting on the arc of a circle of which *B* is the centre.

When the cut has been finished to the required depth and it is required to move ahead, the end of the ladder is pulled as near *F* as possible, and the spud *A* being then in the position of the dotted circle is dropped and the spud *B* is raised. The dredge is then swung round on *A* as a centre until *H* is as near *E* as possible, when the spud *B* is dropped and *A* raised and the dredge has gone ahead a full cut. When the canal is being cut 34 metres wide, the dredge moves ahead 4 meters each time.

The measurements of the work done by these dredges are taken at the end of each completed cut by an engineer of the Canal Company who lives on the dredge. These measurements are signed in duplicate each 12 hours by the canal engineer and the captain of the dredge, also a report of every stoppage which has been made by the dredge and the causes. But very little of the dredged material runs back into the canal after having been deposited on the bank. Three miles of the canal was sounded after it had been dug over one year, and less than 18 inches had run back, and this with a continual passage of small tow-boats

with lighters and barges in tow; and in regard to this I may say, that the climate which, by its heat, moisture, and unhealthiness, is the greatest enemy to the canal during its construction, becomes at once its best friend when it is constructed, because, owing to the rapid growth of vegetation, one year after the banks of the canal have been constructed, they will be so bound together by roots and vegetation that any danger there may have been from sliding or washing will be done away with entirely.

There are seven of these dredges now at work on the Isthmus, and the number of cubic metres excavated by them all during the month of January last was 728,000, or 104,000 cubic metres per dredge, which is the largest amount of work ever done in the same time by any machine. The total number of cubic metres excavated by this company up to January 31 is 5,200,000 cubic metres, or more than one-third the whole amount of work done on the Isthmus. In distance they have excavated 11 kilometers, or 6.6 miles of the main line of the canal.

The "floating disembarker," which is used for the unloading of scows and barges which have been filled by dredges when the material is needed for embankments, consists of two large pontoons placed side by side, with enough space between them for the entrance of one of these dump scows. Upon each of these pontoons is a tower about 30 ft. high, connected at the top by a stiff truss. From the centre of this truss is suspended a ladder around which the buckets revolve. The loaded scow is hauled in between the pontoons, the buckets lowered and set to work. The dredged material is discharged in the required place through a long discharge-pipe.

There is one large floating derrick with a capacity of 60 tons.

The Franco-American Trading Company have a large contract for dredging upon the Pacific side in the valley of the Rio Grande; but thus far they have done no work to speak of.

The dredge used by this company is the single dipper dredge, built by the Pound Manufacturing Company, Lockport, N. Y., and in the manner in which it has to be used on the Rio Grande it is not a success.

The dredged material is dumped from the dipper into a box suspended from a derrick upon a car which runs along the side of the canal. When the box is filled, it is swung away from the canal and emptied. The process is very slow, and owing to the marshy ground it is almost impossible to so lay the track upon which the derrick car runs as to give it sufficient stability.

Owing to the lack of water, the dredges, can only be worked during high tide, and therefore have hardly dug out twice their own length yet, and the question of running their derrick car any distance yet has assumed no importance.

This company owns its machines and imports them in sections, to be erected on the spot. These are some of the principal pieces of machinery which are at work on the Isthmus, but without having been over the line of the canal and seen their storehouses, one can form no idea of the immense amount of material of all kinds which they have on hand. In fact, the whole 45 miles of the canal is nothing but one vast storehouse.

CHAGRES RIVER.

The Chagres River, of course, is the obstacle to the construction of the canal which requires the greatest amount of study to be overcome successfully. It crosses the line of the canal 27 times, and in its upper part is from 100 to 150 feet above it. The first idea was to use the bed of this river, in part, as a part of the canal, but upon a very slight examination it was found that, owing to the immense amount of water which sometimes fell in a few hours, and the extreme rapidity with which it is emptied into the river, there was no way by which it could be controlled so as to be used as part of the canal; and thus, what was at first looked upon as one of the strongest arguments in favor of the Panama route, has since developed into one of the gravest obstacles.

In June, 1883, the Chagres at San Pablo rose 44 feet in four hours, and swept away most of the bridges of the Panama Railway.

The plan which was finally adopted, and is being now put in practice, for the control of both the River Chagres and the Rio Grande on the Pacific slope, is to so change the course of these rivers that in the place of crossing the canal they are carried down on each side of it in special canals where necessary, and the canal proper protected by large masonry walls on each side wherever these deviation canals approach within a dangerous distance.

Then the Chagres is to be further controlled as follows:

A short distance above Matachin, at the junction of the Chagres and the Rio Obispo, the Chagres turns sharply to the east and passes between the Santa Cruz and Obispo mountains. It is between these mountains that a large dam is to be built by which to control the Chagres. This dam will be about three-quarters of a mile long and 150 feet high, with a base of 1,300 feet. The exterior slope will be four to one of broken rock, well revetted by heavy masonry.

Through the mountain Azul to the left of Santa Cruz will be cut a tunnel 600 metres long and 7 metres in diameter, through which will pass the waters of the Chagres. This dam will be built of the material taken from the large cuttings of Obispo and Emperador.

By means of this dam and tunnel the flow of the Chagres can be regulated and in times of flood any surplus water can be held back.

In one way the Chagres has been of some advantage to the construction of the canal. It is navigable for about 20 miles from its mouth, and thus the dredges can be taken up the river and started to work on the line of the canal at all the points where the river crosses the canal within this 20 miles, thus giving a great number of points where work can be carried on.

AMOUNT OF WORK DONE.

The total number of cubic metres of excavation in the canal proper is 122,000,000, and up to January 31, the total amount excavated was 15,000,000 cubic metres, leaving a balance of 107,000,000 cubic metres yet to be excavated in the line of the canal proper, and also all the extra excavation needed to change the course of the Chagres and Rio Grande, and also the improvements in the harbor at Colon.

APPROXIMATE STATEMENT OF THE MONEY WHICH HAS BEEN SPENT.

Excavation 15 millimeters	$30,000,000
Houses, lands, clearing, etc	5,000,000
Machinery, material, etc	36,000,000
Administration in Paris and the Isthmus, expenses of organization, etc., etc	29,000,000
Cash on hand	7,000,000
Total	$107,000,000

To raise the amount of money the liabilities of the company are $150,-000,000, which at 4 per cent. equals $6,000,000 annual interest which the Canal Company now has to pay.

In the above statement of the amount of money which has ben spent, no mention has been made of the $17,000,000, which was the price paid by the canal company for a controlling influence in the Panama Railway, as no one outside the interested parties knows in what manner this sum is to be paid. Although the price seems tremendous to pay for the control of a railway 47 miles long, still, when the importance of the railway to the canal is fully realized, one can see that it is about the best spent money and wisest operation of the canal company. Although the French have now the full control of this railway, they have shown the good sense to leave the management of it entirely in the hands of its former American managers.

Of course, any estimate of the cost of completing the Panama Canal must be purely conjectural. But we must remember that it will not be fair to base any of this estimate upon the actual cost of the work that has been done. Much money has been spent in forming the company and such expenses, much more in buying their working plant, which they have now, and much more has been spent in buying experience and paying for the most costly experiments, the results of which they now have and from which they can profit.

APPROXIMATE ESTIMATE OF THE COST OF FINISHING THE PANAMA CANAL IN EIGHT YEARS.

Excavation, 107,000,000 cubic metres, at 1.50	$160,500,000
Chagres River and harbor	40,000,000
Administration	3,000,000
Total	$203,500,000
Banking and interest, 8 years	80,000,000
Total	$283,500,000
Interest on 283.5 million at 4 per cent	$11,340,000
Interest on money already raised	6,000,000
Annual interest	$17,340,000

which will be due if canal is finished in eight years at above cost. When the canal is opened for ships the company can only charge $3 per ton for saving them 8,000 miles in distance, and it would therefore take 5,780,000 tons yearly to pay the interest. The amount of tonnage which will pass through the canal has been variously estimated from 3 to 8 millions.

Any estimate as to the amount of business which will be done by the Panama Canal when it is finished must be purely conjectural.

The first year the Suez Canal was in operation its revenue from tolls was $900,000, in ten years its revenues were $7,500,000, and now they are $12,000,000 annually.

There are no insurmountable obstacles in the way of the completion of the Panama Canal in a few years. The only question is money, and certainly as long as De Lesseps lives there will be no lack of that.

The management on the Isthmus has been loose and disjointed, but it is improving rapidly now. Undoubtedly money has been wasted, but no greater percentage than in other large enterprises. The work is being pushed in every direction. Contractors are being held to their contracts, and although no one can state the time when the canal will be finished, still no one can advance any proof or reason why it cannot be finished within the next eight years.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

JULY 6, 1886 :—The 226th meeting was held at 7:30 P. M., President Wright in the chair.

On motion of Mr. Seymour, Mr. Bates was made Secretary *pro tem.*

The minutes of the last preceding meeting were read and approved.

Applications for membership were received from :

Prof. I. O. Baker, University of Illinois, Champaign, Ill.

Robert J. Cram, Contracting Engineer, Detroit.

S. C. A. Holth, Mechanical Engineer and Chemist, 226 La Salle street, Chicago, Ill.

W. L. B. Jenney, Architect and Engineer, Chicago, Ill.

Louis Mohr, Consulting Engineer, Chicago, Ill.

A. S. Paré, Patent Solicitor, 204 Dearborn street, Chicago, Ill.

Wm. Scherzer, Assistant Engineer Keystone Bridge Co., Chicago, Ill.

O. C. Simonds, Superintendent Graceland Cemetery, Chicago, Ill.

Angus Sinclair, Editor *National Car and Locomotive Builder*, Chicago, Ill.

The following persons were elected Members :

Sigwald Udstad, Mechanical Draughtsman, C. & N. W. Ry., 315 W. Huron street Chicago, Ill.

Alva M. Van Auken, Resident Engineer F. E. & M. V. R. R., Fremont, Neb.

Geo. T. Wickes, Mining Engineer, Bozeman, Montana.

A letter of thanks from the American Society of Mechanical Engineers was read and placed on file.

The Secretary was instructed to notify the Trustees that the lease for Society rooms was ready for execution.

A paper on GRAVEL ROADWAYS WITH TELFORD FOUNDATIONS, by C. P. Matlack, was read and discussed.

[*Adjourned.*] W. S. BATES, Secretary *pro tem.*

Regular meetings are held on the first Tuesday of each month at 7:30 P. M.

AUGUST 3, 1886 :—The 227th meeting was held at 7:30 P. M., President Wright in the Chair.

The minutes of the preceding meeting were read and approved.

Applications to be admitted to membership were received from :

James Wilbur Carrier, Assistant Engineer, Chicago & Alton R. R., Chicago.

Eugene Dietzgen, Manufacturer of Engineers' Supplies, 774 Sedgwick street, Chicago.

John Herron, Assistant Engineer, Montana Central Railway, Helena, Montana.

Edwin A. Hill, Acting Chief Engineer, Indianapolis, Decatur & Springfield Railway, Indianapolis, Ind.

Otto Luhring, Manufacturer of Engineers' Supplies, 749 N. Wells street, Chicago.

Otto William Meysenburg, Manufacturer, 185 Dearborn street, Chicago.

George Rosen Simpson, Draftsman Chicago Forge & Bolt Co. Bridge Works. Chicago.

John Townsend, Engineer and Manufacturer, 185 Dearborn street, Chicago.

The following persons were elected Members :

I. O. Baker, Professor of Civil Engineering, University of Illinois, Champaign Ill.

Robt. J. Cram, Contracting Engineer, 80 Griswold street, Detroit, Mich.

S. C. A. Holth, Mechanical Engineer and Chemist, 226 La Salle street, Chicago.

W. L. B. Jenney, Architect and Engineer, Chicago.

Louis Mohr, Consulting Engineer, 32 Illinois street, Chicago.

A. S. Paré, Patent Solicitor, 204 Dearborn street, Chicago.

Wm. Scherzer, Assistant Engineer Keystone Bridge Co., Chicago.

O. C. Simonds, Superintendent Graceland Cemetery, Chicago.

Angus Sinclair, Editor *National Car and Locomotive Builder*, Chicago.

Mr. Wright, referring to a paper read by him before the Society, January 15, 1884, on the Rasmusen Cable System as Applied to Street Railways, stated that an experimental section of 3,000 feet in length of this system was being laid by the Chicago West Division Railway Company. A general discussion was had on the different kinds of street railroads and the motive power used thereon.

It was voted that 600 copies of the Constitution and By-Laws and List of Members should be printed.

[*Adjourned.*] L. P. Morehouse, Secretary.

A copy of the *Journal of the Association of Engineering Societies* is sent monthly to each member. If not received, please notify the Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

December 8, 1885:—Regular meeting held, President Holloway in the chair.

Minutes of the last meeting were read and approved.

Resolutions of thanks were received from the Delegates attending the Convention of Civil Engineers, recently held in the city, for courtesies received.

On motion, the correspondence between the Executive Committee on the relation between the Civil and Military Engineers on Government works and the different Societies was turned over to said Executive Committee.

Messrs. Warner and Swasey extended an invitation to the Members of the Club to visit their observatory and inspect the new astronomical telescope recently manufactured by them. The invitation was accepted with thanks.

The report of the Committee on Civil Engineering on Public Works was received, and the question of ratifying the course adopted by the Convention of Engineers was postponed until the next Tuesday evening.

Messrs. Welty, Morse and Kingsley gave notice of a proposed amendment to Article XIII. of the By-Laws, providing for eight, in place of seven, standing committees of the Club; the eighth to be entitled "A Committee on National Public Works," as requested by the Convention held in Cleveland, Dec. 3, 4 and 5, 1885.

Mr. Clarence M. Barber read a paper entitled "Old Bridges Under New Loads."

[*Adjourned.*] M. W. Kingsley, Recording Secretary.

December 15, 1885:—Special meeting, called to consider the report of the Committee upon the Convention of Civil Engineers, held in Cleveland, December 3, 4 and 5, 1885, to consider the relation between the Civil and Military Engineer upon Civil Public Works.

Meeting called to order, President Holloway in the chair. In the absence of both Secretary and Assistant Secretary, M. E. Rawson was elected Secretary *pro tem.*

The discussion was resumed upon the resolution of the previous meeting, to

adopt, as the sense of the Club, the report submitted to the Convention by Messrs. Davis, Corthell and Marx. After an extended discussion of the subject by the Members, the resolution was adopted.

The report referred to is as follows:

To the Convention representing the Civil Engineering Societies of the United States by their delegates assembled at Cleveland, Ohio:

GENTLEMEN:—Your Committee on the "Report of the action of the Convention, said report to be submitted by the delegates to their respective societies," respectfully submit the following as their final report:

The foremost nations of the Old World have organized systems of internal improvements. The United States at present has no such system. The marvelous development of this great country demands some adequate organization of such a system.

In the formation of such an organization, advantage should be taken of the best features of the systems of other nations.

The main reason for the success of such works in foreign countries is due to the fact that they are executed under a civil administration, although the Governments themselves, in other respects, are more essentially military than our own.

The distinguishing feature of these organizations is the employment of the best available talent, of men especially fitted by education, training and experience, to design and execute such works.

Under our present methods, the Government cannot possibly secure such trained skill. The reason is, that no emoluments or reputation, commensurate with the service rendered, or equal to what can be obtained on other civil works, are attained on the public works of our Government.

These facts deter men of experience from entering the service of the Government, and also those who have gained experience therein, from remaining in its employ.

Recognizing that a comprehensive system of public works is necessary, we respectfully suggest that Congress should be asked to establish a Civil Bureau of Public Works; the basis of organization of this bureau to be made the subject of study and report, by a Board appointed by the President of the United States; said Board to consist of seven members—three military engineers, three civil engineers, and one member of the legal profession.

CLEVELAND, OHIO, Dec. 5, 1885.

Professor Eisenmann moved to adopt the first clause of the report of Messrs. Eisenmann, Loweth and Kurth to the Convention, in reference to the perpetuation of its work by the appointment of a Permanent Committee on National Public Works.

Mr. Mordecai moved an amendment to postpone the further discussion of the question until the February meeting.

A very general discussion followed this amendment, and various others were suggested, when the same gentleman presented the following resolution as a substitute, which was adopted:

Resolved, That the Committee heretofore appointed (April 14, 1885, consisting of Messrs. Eisenmann, Rice, Laman, Blunt and Ritchie, in relation to the matter before the Convention) be continued under the name of the Committee on National Public Works, to serve until discharged.

Mr. Whitelaw presented the following, which was adopted:

Resolved, That the Chairman appoint a committee of seven (7), of which he shall be one, to take into consideration and report a programme for the annual meeting in March.

The following resolution by Mr. Blunt was adopted:

Resolved, That the thanks of the Civil Engineers' Club of Cleveland be tendered to the management of "The Hollenden" for the marked courtesy and attention

shown the delegates from various engineering societies of the country to the Convention which was recently called to Cleveland, by this Club, and also for the free use of rooms for certain deliberations of said Convention.

Professor Eisenmann moved that the proceedings of the Convention, as published, be presented to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for publication. Adopted.

[*Adjourned.*] M. E. RAWSON, Secretary *pro tem.*

JANUARY 12, 1886 :—Regular meeting held, Professor Holloway in the chair.

Minutes of the last two meetings were read and approved.

Major Overman presented to the Club the annual report of the harbors on Lake Erie west of Buffalo, except at Erie and the Sandusky river. The Club also received the map of the preliminary surveys of the Lower Mississippi, river through the Secretary of the Commission.

The Corresponding Secretary was instructed to return the thanks of the Club for the same.

Mr. Mordecai offered the following :

Resolved, That the President appoint a Committee of three to nominate two tickets for officers for the ensuing year.

Mr. Blunt offered the following as a substitute, which was adopted :

Resolved, That the Programme Committee be constituted a Committee on Nominations, with instructions to report at the February meeting two lists of candidates for officers for the ensuing year.

Mr. J. L. Gobeille read a paper entitled "Engineering and Mechanical Problem. Relating to Stove Construction." Mr. Gobeille's paper was accompanied with full-sized models and patterns of stoves, and with many drawings.

On motion, the Treasurer was instructed to pay $5 to the Janitor of Case Library

The application of Luther Allen for associate membership, and J. M. Ackley for active membership, were reported favorably upon by the Committee on Membership, and upon motion the gentlemen were elected unanimously.

The Committee on Annual Banquet was instructed to complete the arrangements, and to have the annual meeting and banquet held on separate evenings, if deemed advisable.

[*Adjourned.*] M. W. KINGSLEY, Recording Secretary.

FEBRUARY 9, 1886 :—Regular meeting held.

Minutes of last meeting were read and approved.

The Committee on Programme, as a nominating committee, presented the following names from which to choose officers for the ensuing year :

President, Charles Latimer and William H. Searles. *Vice-President*, Ambrose Swasey and S. T. Wellman. *Corresponding Secretary*, J. S. Oviatt and E. H. Jones. *Recording Secretary*, C. M. Barber and J. L. Gobeille. *Treasurer*, S. J. Baker and N. P. Bowler. *Member of Board of Managers of Association of Engineering Societies*, Augustus Mordecai and M. E. Rawson.

(Signed) W. P. RICE,
N. B. WOOD, } Com.

The Committee on Banquet reported progress, and recommended the Stillman House as the place for holding the annual banquet.

Mr. Latimer presented a picture of Mr. Ashbel Welsh, a prominent civil engineer and late President of the American Society of Civil Engineers.

Mr. C. P. Leland presented a picture of Mr. Charles Paine, the First President of the Club. Both gentlemen received a vote of thanks for their donations.

Mr. Eisenmann presented a publication entitled "A Rational Policy on Public Works;" also, a London publication on Engineering.

The following publications were also received: Proceedings of the Engineers' Club of Philadelphia, Transactions of the Technical Society of the Pacific Slope (ordered bound), Connecticut Association of Civil Engineers and Surveyors, American Institute of Mining Engineers, Proceedings of Association of Dominion Land Surveyors, Engineers' Club of St. Louis, Nebraska Association of Civil Engineers and Surveyors, American Society of Civil Engineers, American Association of Mining Engineers, Report of the Massachusetts Drainage Commission.

W. P. Rice reported the death of Mr. J. S. Lawrence, Member of the Club, at Buffalo, N. Y., at the age of 74 years and 8 months, and moved that a Committee be appointed to take appropriate action on the same. Adopted, and Messrs. L. C. Overman, Chas. Latimer and W. P. Rice were appointed such Committee.

A vote of thanks was extended to Mr. Clark, of Boston, for the report received of the Massachusetts Drainage Commission.

The Committee appointed to obtain the portraits of deceased Members reported progress.

A recess of 10 minutes, for consultation, was taken.

Mr. J. L. Culley read a paper entitled "Hillside Drainage." After discussion the Club adjourned. F. C. BATE, Assistant Recording Secretary.

MARCH 9, 1886:—Regular and Annual Meeting held, President Holloway in the chair.

Minutes of last meeting were read and approved.

The annual reports of the Treasurer, Recording Secretary, and Member out of the Board of Managers of the Association of Engineering Societies were received and ordered placed on file. The Treasurer's report showed: total receipts $1,157.16, disbursements $861.35; balance, $295.81.

The President appointed Messrs. J. L. Culley, Thomas West, and N. B. Wood as tellers to count the votes received by letter for officers of the Club for the ensuing year.

Letters were received from Major L. Cooper Overman, U. S. A., and Mr. Wm. M. Barr, tendering their resignations as Members of the Club, which, upon the recommendation of the Committee on Membership, were accepted.

The petition of M. Baackes and Bruno Kniffler for active membership were received, and upon the recommendation of the Committee on Membership, they were elected.

Books and pamphlets were received as follows: Terminal Facilities at the Port of New York, by Gratz Mordecai; Atlantic and Pacific Ship Railway across the Isthmus of Tehuantepec, from James B. Eads; lithographic sheets of Rolled Beams, from Cooper, Hewitt & Co.

The tellers appointed to count the ballots reported the following-named persons elected: *President*, Charles Latimer; *Vice-President*, Ambrose Swasey; *Corresponding Secretary*, James S. Oviatt; *Recording Secretary*, Clarence M. Barber; *Treasurer*, S. J. Baker; *Member of Board of Managers of the Association of Engineering Societies*, M. E. Rawson.

A vote of thanks was tendered the retiring officers.

President Holloway read a short report, his regular address being reserved for the evening of the annual banquet.

On motion, the Club took a recess until Saturday evening, March 13, for the annual banquet at the Stillman House.

MARCH 13, 1886:—Stillman House.—Members and invited guests assembled at the annual banquet of the Club.

President Holloway delivered his annual address, which was followed by the annual supper.

The rest of the evening was spent in listening to toasts and speeches, and in social intercourse. M. W. KINGSLEY, Recording Secretary.

MARCH 23, 1886 :—Special semi-monthly meeting held, President Latimer in the chair.

The President in his introductory address complimented the retiring President and officers for the satisfactory manner in which they had fulfilled the various positions assigned them. At the conclusion of his address, the President announced the committees, to be appointed at the next regular meeting, as follows :

Publication and Library—M. E. Rawson, M. W. Kingsley and James Ritchie.

Membership—John Whitelaw, Alex. E. Brown and B. F. Morse.

Civil Engineering and Surveying—Wm. H. Searles, J. D. Varney, J. L. Culley, J. H. Sargent and C. G. Force.

Architecture.—J. N. Richardson, J. M. Blackburn, C. O. Arey, Theo. Rosenberg and F. A. Coburn.

Subjects Pertaining to Scientific Pursuits—Prof. E. W. Morley, W. R. Warner, Geo. Bartol, N. S. Possons and G. A. Hyde.

Railroad Engineering—A. Mordecai, James L. Sterling, W. C. Jones, J. C. Brewer and L. H. Clark.

Mechanical Engineering—J. F. Holloway, S. T. Wellman, John Walker, J. H. Greenwood and Joseph L. Gobeille.

Mr. Wm. T. Blunt, having removed to California, tendered his resignation as an active member of the Club, and requested that he be re-elected a corresponding Member. Resignation accepted, and request as to corresponding membership referred to the Committee on Membership.

The resignation of Mr. J. B. Merriam was received and referred to the same Committee.

On motion of Mr. Varney, Mr. W. H. Searles was elected to fill the vacancy on the Committee on Public Works, caused by the removal and resignation of Mr. Blunt.

Mr. Eisenmann stated that there would be a meeting of the Committee on Public Works on the 29th or 30th inst. He stated that about 25 Societies were now in the movement.

Mr. Walter P. Rice read the memoir prepared by the Committee on the Death of Mr. James S. Lawrence, Member of the Club. Mr. Rice also presented a sketch of Mr. Lawrence's life.

Mr. Latimer stated that although his acquaintance with Mr. Lawrence began only about four years ago, he had learned to love and honor him. He was peculiarly calculated to win confidence and affection. He was always earnest and faithful in whatever he undertook. He was a regular attendant at the meeting, of the Club and of the Weights and Measures Society. In his death we have lost not only a Member, but a true and earnest friend.

On motion of Mr. Wood, the report of the Committee was adopted, and the report and remarks were ordered spread upon the minutes of the Club.

Mr. Latimer spoke of the loss the Club had sustained in the death of Mr. J. H. Devereux, Member of the Club.

Mr. J. F. Holloway, on behalf of the Committee appointed for this purposes presented the following resolutions :

Resolved, That it is with much sorrow and regret that we, as Members of the Civil Engineer's Club of Cleveland are called upon to transfer from our membership list to the roll of our honored dead the name of Gen. J. H. Devereux.

That in the death of General Devereux we lose a Member who was among the first to join us, and who, while his numerous duties and cares left him no time in which to attend our meetings, ever expressed a warm interest not only in the welfare of the Club, but as well in the profession of engineering, with which in early life he became identified, and which he ever afterward held in high esteem.

That, in the life of our esteemed Member, there has been exemplified the outcome of a career which, beginning in a firm determination to deal justly by all

men; to seek no favors not justly earned; to accord to others what he asked for himself, coupled with a most courteous treatment of all, irrespective of wealth or position, has not only added lustre to an honored name, but has, as well, left an example all will do well to follow.

That, as Members in an association in which he had many warm and trusted friends, we desire to add our tribute of respect to his memory, our high appreciation of his life's record, and our sympathy with the family and those friends who, knowing him better, will miss him most; and that it is the sense of this meeting that these resolutions be spread upon the minutes of the Club, and that a copy be sent to the family of our deceased Member, coupled with the request that his portrait be sent us to take its place among those who, as engineers and men of integrity and ability, have aided the world's progress and benefited their race.

In supplementing the report, Mr. Holloway said that he had not the pleasure of an intimate acquaintance with Mr. Devereux, but that a year ago he had called upon him to ascertain if he could attend the annual meeting and make some remarks. Mr. Devereux was about to depart on a journey, but with kindly consideration he laid aside his work and evinced a sincere interest in the welfare of the Club, and wished that he could attend the meeting, but his approaching journey rendered it impossible. He fulfilled the duties of a difficult position with a high sense of right and justice.

Mr. J. H. Sargent said that Mr. Devereux came to Cleveland at the age of seventeen years from school in the East, and took the position of rodman upon a survey of which he (Mr. Sargent) had charge. Other young men just out of school did not think much of engineers from the backwoods. Not so with Mr. Devereux; he was always cordial and good-natured, and his heart was in his work. He began work with the Cleveland & Columbus road (now a part of the C., C., C. & I. R. R.), and ended his life with it.

Mr. Mordecai said that in his intercourse with Mr. Devereux he had always been impressed by his charm of manner, by the interest with which he entered into the affairs of those who sought advice and assistance from him. He spoke of what Mr. Devereux had done for the A. & G. W., now the N. Y., P. & O. Railroad, and of the fact that he always treated his men with kindness. Mr. Mordecai said that his death seemed especially calamitous at this time, when we are on the verge of a struggle between labor and capital.

Mr. Latimer said that before Mr. Devereux took charge of the A. & G. W. R. R. there was no harmony. The principal officers were in New York, and when he came he called the officials together and said: "We must have harmony in this work, and you must all strive with me to make this property what it ought to be." Immediately there was a calm; it was like oil upon the troubled waters. He understood the art of managing men; he governed without appearing to govern. When he appointed me Chief Engineer of the road, he said: "I shall not ask you for details, but results." With his management each officer had the opportunity to exhibit whatever ability he had, and each strove to make his work good. Mr. Devereux knew that his men required rest, and he strove that they should have it. He ordered that no work should be done in the offices on Sunday; no passenger or excursion trains were permitted to start on that day; the only rains run were for the mails and perishable freight. If men could be handled as he had desired, there would be no need of labor organizations in the country. He was interested in everything. Like the sage of old, he could say; "I am a man, and nothing that concerns humanity do I deem a matter of indifference to me." In all the work of his life, the desire to serve his God animated him.

On motion of Mr. Eisenmann, the report of the Committee was accepted and their recommendations adopted.

Mr. Rosenberg suggested that it was desirable that the various Committees of the Club should meet and elect their Chairman, who would constitute the Committee on Programme.

Mr. Eisenmann asked if the meetings were to be held monthly or semi-monthly.

Mr. Latimer said there should be meetings every two weeks, and that a Chairman should be selected.

In response to a question, Mr. Holloway stated that no extra expense would attend the holding of extra meetings except notifying the janitor.

Mr. Wood stated, in reference to natural gas, that in two wells sunk by Messrs. Lampson & Sessions the specific gravity of the gas was 689 and 667 to 1,000 of air ; 19 cubic feet of Cleveland gas would weigh a pound, while it required 23½ cubic feet of Pittsburgh gas to the pound, so that Cleveland gas is the more valuable.

[*Adjourned.*] C. M. Barber, Recording Secretary.

JAMES S. LAWRENCE.—DIED JANUARY 25, 1886.

BY WALTER P. RICE.

James S. Lawrence was born near the city of London, May 25, 1811, and came to this country in 1836, when twenty-five years of age, spending the first ten or twelve years in various occupations, and visiting England twice prior to 1852.

In June, 1847, he entered the service of the Pennsylvania Railway Company, and was engaged as Assistant Engineer on the surveys between Huntingdon and the summit of the Allegheny Mountains. When the work was put under contract, he was in charge of the section of road between Huntingdon and Jack's Narrows. This work was completed about 1850, when he left the service of the company. Edward Miller was Chief Engineer of the road at this time. Mr. Lawrence was held in high regard by the company. In 1859 he went to Central Park, New York, as assistant to Mr. Olmstead, where he remained until 1864. After leaving, he was recalled to finish work connected with the Lake and Ramble.

He next entered the employ of the United States Government, where he remained to the time of his death, a period covering twenty-one years. He commenced under Captain Tardy, and served as Assistant Engineer with Colonels Blunt, Wilson, McFarland, General Cram and others.

He was first employed in the United States service on the construction of Fort Niagara, and as Assistant Engineer on Lake Ontario from 1866 to 1879, until he left that district to accept a position with Colonel John M. Wilson on Lake Erie.

His active duties ceased on December 4, 1885, and he arrived at his home December 7, sick and enfeebled. Mr. Lawrence died January 25, 1886, at his home in Buffalo, N. Y., after an illness of 7 weeks, at the age of 74 years and 8 months.

Previous to his death he suffered somewhat from malaria and rheumatism, consequent upon 4 months' exposure on Maumee Bay, in directing dredging operations in connection with the proposed "straight channel," a work of considerable magnitude. He was a widower and leaves but one daughter.

He became a member of the Civil Engineers' Club of Cleveland, April 3, 1880, at its first regular meeting,

[Following the reading of the notice of the death of Mr. Lawrence and a brief

sketch of his life and professional services, Mr. Rice paid the following tribute to his memory.]

As I look back over a period of more than five years of professional association with Mr. James S. Lawrence, the last years of his well-spent life, I cannot but think that the profession and the Civil Engineers' Club of Cleveland have suffered a loss. One of those lives which make us feel that the world is better for their presence, has gone out; and as I was so fortunate as to enjoy to a large extent his confidence and the influence of his character, perhaps the following humble estimate may be gratifying to those of the Club who did not enjoy as intimate an acquaintance.

His traits of character were strongly defined. Perhaps the most noticeable was his remarkable faculty of observation; nothing, however insignificant, escaped his attention. Closely allied were his methodical habits, "a place for everything and everything in its place." Method and precision characterized all he undertook. Sensitive by nature, conscientious to a fault, and with the keenest sense of honor he has been well described by one who knew him as "a thorough, Christian gentleman." Surely, no higher tribute could be paid.

In my association with Mr. Lawrence on Government work, I found him to be an engineer of excellent judgment and varied experience. Although nearly 75 years of age, he remained in active charge of harbor work up to almost the day of his death, which to those acquainted with the exposure and hardships often attendant upon this class of work, will seem astonishing. Twenty-one years of faithful service on the Lakes have not passed by without leaving many landmarks to recall the life and services of Mr. James S. Lawrence, a civil engineer of the old school, and a gentleman whose memory will long be cherished.

APRIL 13, 1886:—Regular meeting held, President Latimer in the chair. Minutes of last meeting were read and, after some correction, were approved.

The resignation of Mr. Daniel Appel was read and referred to the Committee on Membership.

Mr. Eisenmann presented the following resolution, which was unanimously adopted:

Resolved, That the thanks of this Club are due and are hereby tendered to our retiring President, Mr. J. F. Holloway, for the able, zealous and faithful manner in which he has performed the duties of that office, and we feel that the large increase in membership and the great success that the Club has attained is largely due to his earnestness, ability and ceaseless efforts to promote its best interests.

Mr. Holloway returned his sincere thanks to the Members for the sentiments expressed in the resolution.

On motion, a rack, with hooks for hats and overcoats, was ordered placed in the room.

The Club was notified that the name of the Committee on Public Works has been changed to "The Council of Engineering Societies on National Public Works."

The Committee on the Sixth Annual banquet reported a cash balance on hand of $15.25.

The standing committees for the ensuing year, as announced at the last meeting, were formally appointed.

Mr. James Ritchie read a valuable paper on the Garfield Monument, which was very generally discussed by the members, and, on motion, it was decided to continue the discussion at the special meeting to be held April 27, 1886.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

APRIL 27, 1886 :—Special semi-monthly meeting, at the office of the City Civil Engineer, City Hall. President Latimer in the chair; 36 Members present.

The report of the Committee on Programme being called for, W. H. Searles, Chairman of the Committee, reported as follows:

Members of the Committee on Programme, composed of the chairmen of the various standing committees: Wm. H. Searles, Chairman; Prof. E. W. Morley, J. L. Gobeille, A. Mordecai and Theodore Rosenberg. The Committee met and prepared the following calendar for the year 1886-7: Papers to be read on the regular meeting nights held on the second Tuesday evening of each month, and reports from the various professions or branches represented in the Club. At the special semi-monthly meetings, held on the fourth Tuesdays of each month, except July and August, as follows:

PROFESSIONS.	PAPERS.	REPORTS.
Civil Engineers and Surveyors	May 11. Oct. 12, April 12.	Sept. 28. Feb. 22.
Railroad Engineering	Jan. 8. Nov. 9.	Oct. 26, March 22.
Mechanical "	July 13, Dec. 7.	Nov. 23, April 26.
Architecture	Aug. 10, Jan. 11.	May 25. Dec. 21.
Subjects pertaining to scientific pursuits	Sept. 14, Feb. 8.	June 22, Jan. 25.
Annual meeting	March 8, 1886.	

The following resolution, by Mr. Mordecai, was adopted:

That the Chairman of the Committee on Programme be requested to present the following resolution to the Club at its next meeting:

Resolved, That until further ordered, there shall be a meeting of the Club on the fourth Tuesday evening of each month, except the months of July and August, for the purpose of hearing the regular semi-annual reports of the standing committees and for such informal matters as may be brought before the meeting.

On motion of Mr. Mordecai, the Committee decided to meet quarterly to discuss all matters pertaining to the duties of the Committee.

(Signed) THEO. ROSENBERG, Sec'y *pro tem.* of Committee on Programme.

On motion, the report was adopted.

On motion of Mr. Searles, the Secretary was instructed to notify the Members of the meetings on the fourth Tuesday evenings of the month.

An acknowledgment of books sent to Japan was read.

A communication was read from Mr. Eisenman, Secretary of the Council of Engineering Societies on National Public Works, stating that 130 copies of the proceedings of the Council had been sent the Club for distribution.

The discussion of Mr. Ritchie's paper on the Garfield Monument was then resumed.

At the close of the discussion, a vote of thanks was tendered to Mr. Frank Ford, engineer in charge of work on the monument, who was present as an invited guest and took part in the discussion.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

MAY 11, 1886:—Regular meeting held, President Latimer in the chair.

Minutes of last meeting were read and approved.

On motion of Mr. Eisenmann, the Secretary was instructed to mail copies of the addresses of the Committee of the Executive Board of the Council of engineering societies to all the Members.

Application was made by a literary club of young men, graduates from Adelbert College, for permission to use the club-rooms two evenings each month for literary purposes. Referred to the Committee on Publication and Library, with power to act.

The resignation of Mr. A. B. Richmond was received and referred to the Membership Committee.

The President read a letter from Mr. Keller, architect of the Garfield monument, in regard to the foundations and superstructure.

The following was presented by Mr. Rice :

Whereas, The discussion of the Garfield monument has, to our regret, been construed as influenced by personal motives ; and in justice to the grave public interests, trusts and professional opinions involved, therefore

Resolved, That this Club, through its President, appoint an expert committee of five members, who shall request the Trustees of the Garfield Monument to afford access to all plans, specifications, details, etc., and all other information for its use, and to give the Committee every facility for making a thorough examination of all the engineering questions involved ; said Committee to report its findings at the earliest possible date.

After some discussion, the resolution was adopted by a standing vote of 19 to 5.

Mr. J. D. Varney presented an interesting paper, entitled "The Metric System as applied to Land Surveying."

A general discussion of the paper followed.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

MAY 25, 1886 :—Special semi-monthly meeting held, President Latimer in the chair.

Reports of committees were called.

Mr. Blackburn, from the Garfield Monument Committee, reported that Mr. J. H. Wade, President of trustees of the monument, had received Mr. Sargent, the chairman of the Committee, very courteously, and offered to send for Mr. Keller, the architect of the monument, in order to afford the Committee every opportunity for obtaining all necessary information for making its report.

The question of employing a stenographer, and of printing "flyers" or leaflets of the proceedings, was discussed and referred to the Committee on Publication and Library.

The Secretary reported the receipt of books from the Heisler Electric Light Company, from Charles Paine, of the Philadelphia Natural Gas Company, and Hudson's Table's for Calculating Earthwork, from the publishers.

Theodore Rosenberg, Chairman of the Committee on Architecture, read his semi-annual report, which formed the basis of a very interesting discussion on architecture.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

JUNE 8, 1886 :—Regular meeting held. President Latimer absent ; Vice-President Swasey in the chair.

Minutes of the last two meetings were read and approved.

The Committee on Library and Publication reported as follows on matters referred to it at previous meetings : That it does not advise the sub-letting of the Club room to the literary club who applied for the same ; that it recommends the employment of a stenographer for reporting the proceedings of the Club, at an expense not to exceed $2.50 per meeting ; that it is not prepared to recommend that verbatim reports of the discussions of the Club should be published in the papers without the consent of the Club ; that it is not prepared to recommend the publication of "flyers," as it would add to the expense of the Club and necessitate an increase of the annual dues.

The report of the Committee was accepted.

The report of the Committee appointed to obtain information relative to the Garfield monument was received and ordered printed in the proceedings of the Club. The Committee was discharged with thanks.

A vote of thanks was tendered to the Architect, Trustees and Engineer of the monument, and to all who had aided the Committee in its work.

Mr. A. Mordecai read a paper entitled "The Effects of Alignment and Grade in the Operation of Railroads." A discussion of the paper followed.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

JUNE 22, 1886:—Special meeting held. In the absence of both President and Vice-President, Mr. J. H. Sargent was called to the chair.

The reading of the minutes of the last meeting was dispensed with.

The report of the Committee on Subjects Pertaining to Scientific Pursuits being in order, Mr. W. R. Warner read an interesting paper entitled Progress in Astronomy, and Mr. N. S. Possons a paper entitled "Progress in Electric Lighting." A very general and profitable discussion followed the reading of the papers.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

JULY 13, 1886:—Regular meeting held, President Latimer in the chair.

Minutes of the meeting of June 8, 1886, were read and approved.

On motion of Mr. Barber, the Club decided to hold its annual picnic. Also, that the President appoint a Committee on picnic, of which he shall be Chairman, with power to act. The following gentlemen were appointed as such Committee: Chas. Latimer, J. F. Holloway, S. J. Baker, A. Mordecai, M. E. Rawson and C. M. Barber.

A resolution by Mr. Barber was adopted, instructing the Committee on Library and Publication to prepare and send to each Member a short circular, giving the names of the officers and standing committees, and containing a calendar.

The same Committee was also instructed to date the employment of the stenographer back to March 23, 1886, the time when such services were commenced.

President Latimer gave a brief account of the first day's meeting of the American Society of Civil Engineers at Denver, and regretted that the Cleveland Club was not better represented.

Mr. Mark L. Deering then read a paper entitled "Wood Pulp, and Some of its Peculiarities." The paper was read by Mr. Gobeille, while Mr. Deering explained the exhibits. The paper was very interesting, and nearly all took part in its discussion.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

RAINFALL RECEIVED AND COLLECTED ON THE WATER-SHEDS OF SUDBURY RIVER AND COCHITUATE AND MYSTIC LAKES.

By Dexter Brackett, Member of Boston Society of Civil Engineers.
[Read May 20, 1886.]

Only a portion of the rainfall falling on any water-shed can be collected and made available for the purposes of water supply, the remainder being absorbed by the soil or evaporated from the surfaces of the streams and ponds. It is, therefore, evident that the percentage of the rainfall which can be collected in the streams or ponds is the basis which must be used in all calculations relative to the quantity of water to be derived from a given water-shed, or the size of storage reservoirs required to furnish a given supply. Very few records of this nature have been kept in this country, and the percentage of the yearly rainfall which could be depended upon for purposes of water supply has been generally over-estimated. The tendency of some engineers has been to base their conclusions upon averages, overlooking the fact that the value of any water supply should be based upon its minimum yield. The value of records of this character is enhanced by the care used in taking the observations, and by the length of time covered by the records. As the percentage collectible is dependent upon the character of the soil, the distribution of the rainfall, the climate and the general character of the water-shed, these facts should be considered in any application of the results to other localities.

The Sudbury River, above the point where the water is taken for the supply of the city, has a drainage area of about 76 square miles. The drainage slopes are generally quite steep and are not highly cultivated; hence a rather large percentage of the rainfall may be expected to reach the brooks and streams. Lake Cochituate has a drainage area of 18.87 square miles, including water surfaces. The district is generally flatter than the Sudbury River water-shed, and the lake is surrounded by meadows which retain the water after a rain. The water-shed of Mystic Lake is very similar in character to that of the Sudbury River; the greater portion of the basin is gravel and sand underlain by rock which occasionally crops out on the hills. The area of the water-shed, including water surfaces, is 27.75 square miles. The following tables show the monthly and yearly rainfall, rainfall collected and percentage collected

on the different drainage areas ; also the quantity received and collected during the four months of minimum collection, viz., July to October. The averages for the last eleven years on the Cochituate water-shed are given for the purpose of comparison with the other records, which cover about the same length of time.

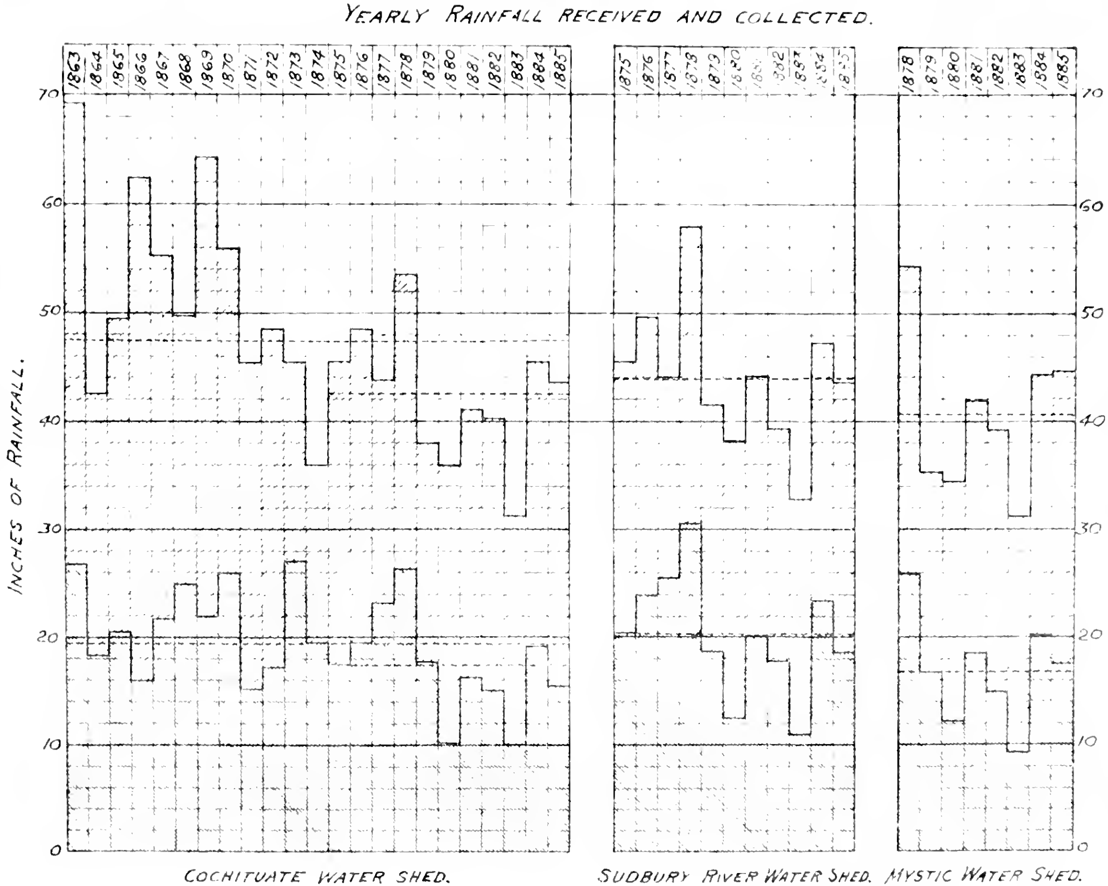
INCHES OF RAINFALL ON THE WATER-SHED OF LAKE COCHITUATE.

YEAR.	Jan.	Feb.	Mar.	Ap'l.	May.	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Tot'ls	4 mos., July-Oct.
1863	4.10	4.38	3.57	11.34	2.66	1.98	14.12	5.61	3.39	4.56	8.54	5.05	69.30	27.68
1864	3.37	0.98	8.14	4.02	2.81	0.58	1.06	3.56	1.52	6.50	5.45	4.28	42.60	12.64
1865	4.93	1.45	5.48	2.18	8.25	0.91	3.10	3.36	1.65	6.99	4.78	3.31	19.46	15.11
1866	1.44	5.80	3.92	1.94	6.46	4.80	13.35	3.98	8.36	3.43	4.52	4.32	62.32	29.12
1867	2.76	5.40	5.65	2.43	6.16	2.95	5.36	12.36	1.08	7.27	2.63	1.90	56.25	26.07
1868	3.70	1.18	2.51	5.61	8.12	2.95	2.16	7.38	7.69	1.19	6.77	0.45	49.71	18.42
1869	3.71	7.07	7.52	2.57	7.59	3.68	2.63	2.34	8.49	9.50	3.26	5.98	64.24	22.96
1870	7.85	4.68	6.04	8.81	3.14	4.05	3.10	2.03	0.64	7.96	4.40	3.19	55.89	13.73
1871	1.31	2.30	5.02	2.29	5.66	5.96	2.20	3.56	1.46	5.38	7.01	3.24	45.39	12.60
1872	1.86	1.37	3.06	1.71	3.24	4.27	5.55	9.76	6.29	3.69	4.22	3.42	48.47	25.29
1873	4.24	2.43	3.98	2.69	3.21	0.38	4.08	7.17	2.62	6.11	4.54	3.95	45.43	19.98
1874	2.95	2.90	1.19	6.36	3.10	4.79	3.16	4.83	1.55	1.04	2.05	1.70	35.93	10.58
1875	2.42	3.15	3.74	3.23	3.56	6.24	3.57	5.53	3.43	4.85	4.83	0.91	45.49	17.38
1876	1.83	4.21	7.43	3.21	2.80	1.60	9.49	2.19	3.98	2.00	6.59	3.13	48.49	17.66
1877	3.19	0.53	7.79	3.24	3.73	2.61	2.77	3.35	0.46	8.14	6.94	1.02	43.80	14.72
1878	5.77	5.93	4.20	5.63	0.83	3.33	3.47	6.94	1.12	5.15	6.09	5.12	53.58	16.68
1879	2.00	3.05	3.90	4.69	1.20	4.14	3.38	6.43	1.74	0.90	2.98	3.60	38.01	12.45
1880	3.07	4.05	2.83	2.94	2.03	1.25	7.00	3.81	1.69	2.95	1.70	2.56	35.88	15.45
1881	5.56	4.43	4.79	1.71	3.18	1.83	2.78	1.13	2.13	2.87	3.85	3.83	41.09	8.91
1882	5.93	3.96	2.76	1.89	4.73	1.87	3.19	1.14	9.20	2.22	0.93	2.17	40.29	16.05
1883	2.88	3.59	1.76	2.27	3.95	1.81	2.88	0.39	1.31	5.16	2.06	3.14	31.20	9.74
1884	4.39	6.04	4.50	3.80	2.92	3.88	4.42	4.19	0.90	2.59	2.33	5.31	45.57	12.40
1885	5.25	3.98	1.09	3.71	3.46	2.96	1.78	7.01	1.63	5.26	5.26	2.32	43.66	15.63
Averages	3.68	3.73	4.40	3.85	4.06	3.13	4.56	4.71	3.14	4.60	4.12	3.22	47.50	17.01
Av. 1875-85	3.85	3.91	4.07	3.31	2.94	3.14	4.09	3.86	2.50	3.82	3.96	3.00	42.15	14.28

INCHES OF RAINFALL COLLECTED ON THE WATER SHED OF LAKE COCHITUATE, 1863-1885.

YEAR.	Jan.	Feb	Mar.	Apr.	May.	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Tot'ls	4 mos., July-Oct.
1863	1.93	3.11	3.71	4.42	1.44	0.67	2.97	1.51	0.98	1.32	2.65	2.17	26.88	6.78
1864	2.39	1.56	4.05	2.65	1.62	0.49	0.41	0.68	0.19	1.43	1.25	1.33	18.35	3.01
1865	2.15	1.74	4.66	2.70	4.70	0.34	0.46	0.47	0.45	0.70	1.00	1.13	20.50	2.08
1866	0.73	2.84	1.76	1.63	1.29	1.10	1.20	0.64	1.34	0.93	0.99	1.56	16.01	4.11
1867	1.10	5.24	3.50	2.87	2.20	0.65	0.59	2.10	0.31	1.02	1.10	1.12	21.80	4.02
1868	1.22	1.12	3.84	3.18	6.17	1.59	0.45	1.18	1.85	0.95	1.96	1.17	21.98	4.43
1869	1.82	1.84	3.31	2.40	2.20	1.07	0.74	0.58	1.10	2.37	1.30	3.17	21.90	4.79
1870	4.71	3.93	3.38	6.87	1.65	0.97	0.53	0.41	0.86	1.11	0.88	0.77	26.08	2.91
1871	1.03	2.28	2.53	1.58	2.00	0.87	0.43	0.85	0.39	0.69	1.30	1.21	15.16	2.36
1872	1.15	0.93	1.44	3.08	1.10	1.49	0.14	1.32	1.70	1.69	2.00	1.21	17.22	4.85
1873	3.09	1.57	3.89	6.09	2.06	0.45	0.62	1.40	0.78	2.04	1.86	2.68	27.13	4.84
1874	3.55	2.19	1.84	3.19	2.78	1.96	0.95	0.92	0.53	0.52	0.58	0.51	19.52	2.92
1875	0.13	2.92	2.66	3.15	1.39	1.48	0.25	0.62	0.60	1.19	1.96	1.22	17.57	2.66
1876	1.09	1.78	5.19	4.20	1.43	0.51	0.81	0.29	0.88	0.49	1.85	0.99	19.51	2.50
1877	1.20	1.37	6.81	3.24	2.04	0.92	0.65	0.67	0.16	1.16	2.69	1.96	23.17	2.91
1878	3.25	3.97	5.40	2.86	1.66	0.76	0.47	0.84	0.29	0.73	2.07	1.04	26.34	2.33
1879	1.29	2.32	3.39	4.18	1.40	0.77	0.33	0.95	0.61	0.60	0.72	1.04	17.81	2.49
1880	1.47	2.24	1.79	1.57	0.44	0.06	0.33	0.23	0.24	0.48	0.83	0.61	10.30	1.29
1881	1.19	2.23	5.66	1.79	1.26	1.31	0.16	0.09	0.23	0.18	0.81	1.40	16.34	0.66
1882	1.84	3.00	3.67	0.93	1.55	0.62	0.06	0.07	0.97	0.84	0.58	0.92	15.05	1.94
1883	0.84	1.59	2.04	1.66	1.25	0.07	0.02	0.07	0.62	0.59	0.11	0.94	10.11	1.30
1884	1.84	2.86	4.67	4.00	1.39	0.67	0.26	0.61	0.13	0.34	0.62	1.82	19.21	1.34
1885	1.90	2.00	2.21	2.36	1.61	0.43	0.00	0.33	0.25	0.79	2.05	1.64	15.57	1.37
Averages	1.79	2.37	3.53	3.10	1.97	0.81	0.56	0.74	0.70	0.96	1.37	1.50	19.43	2.96
Av. last 11 yrs	1.46	2.39	3.95	2.75	1.42	0.69	0.31	0.43	0.48	0.67	1.33	1.49	17.36	1.89

PLATE I.



YEARLY RAINFALL RECEIVED AND COLLECTED.
INCHES OF RAINFALL.
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
70
60
50
40
30
20
10
0
COCHITUATE WATER SHED.
SUDBURY RIVER WATER SHED.
MYSTIC WATER SHED.

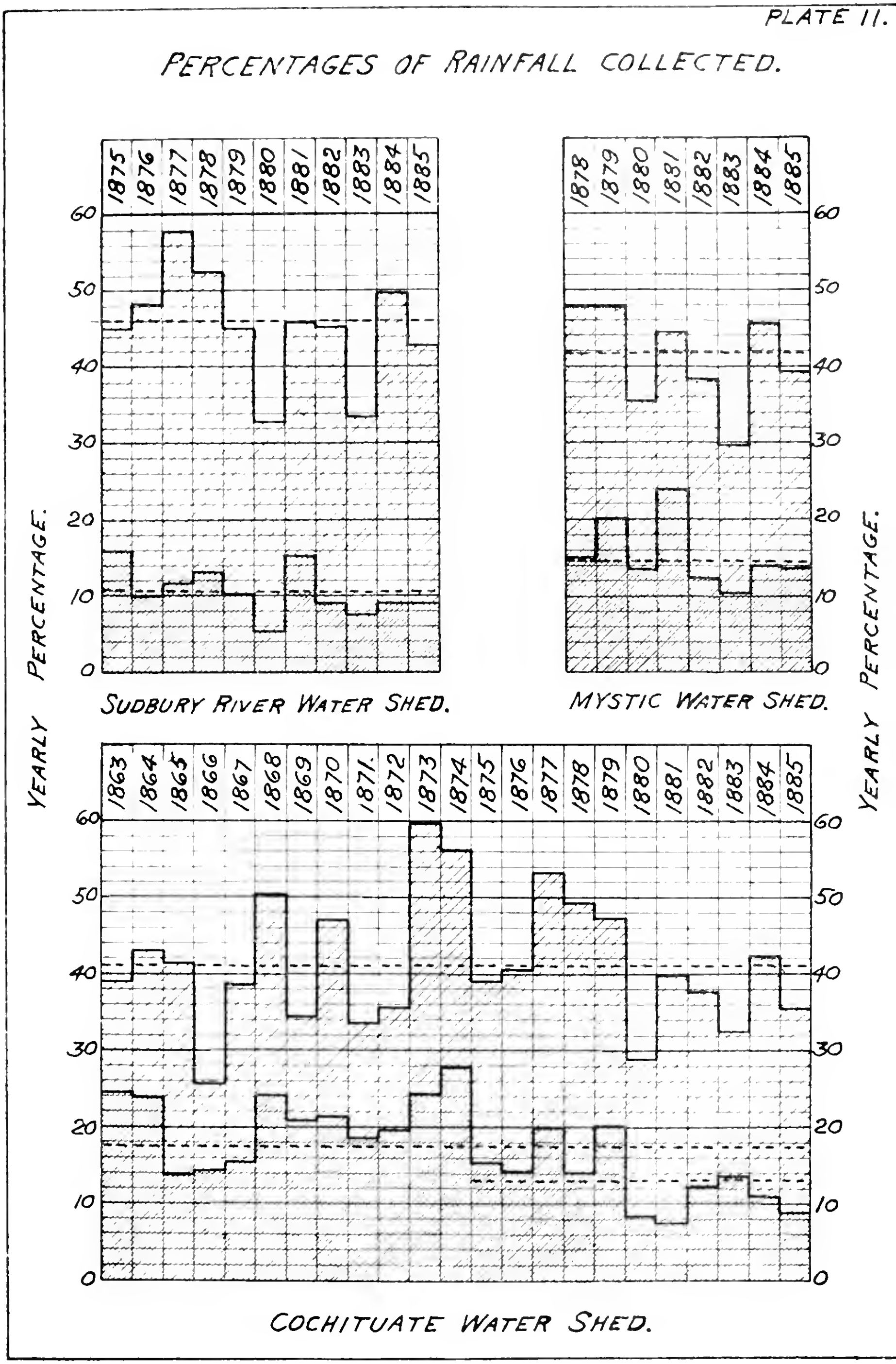


PLATE II.
PERCENTAGES OF RAINFALL COLLECTED.
1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885
1878 1879 1880 1881 1882 1883 1884 1885
60 50 40 30 20 10 0
YEARLY PERCENTAGE.
SUDBURY RIVER WATER SHED.
MYSTIC WATER SHED.
1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885
COCHITUATE WATER SHED.

PERCENTAGE OF RAINFALL COLLECTED ON THE WATER-SHED OF LAKE COCHITUATE.

Year.	Jan.	Feb.	Mar.	April	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly.	July to Oct.,inc
1863...	47.	71.	104.	39.	54.	34.	21.	27.	29.	29.	31.	43.	38.8	24.5
1864...	71.	159.	48.	66.	57.	84.	39.	19.	32.	22.	23.	31.	43.1	23.8
1865...	43.	39.	85.	124.	57.	37.	15.	14.	27.	10.	21.	34.	41.4	13.8
1866...	51.	49.	45.	84.	20.	23.	9.	16.	16.	27.	22.	36.	25.7	14.1
1867..	40.	97.	62.	118.	34.	22.	11.	17.	29.	14.	42.	59.	38.7	15.4
1868..	33.	95.	153.	62.	76.	54.	21.	16.	24.	80.	29.	261.	50.2	24.0
1869...	49.	26.	44.	97.	29.	29.	28.	25.	13.	25.	40.	53.	34.2	20.9
1870...	60.	84.	56.	78.	53.	24.	17.	20.	133.	14.	20.	24.	46.7	21.2
1871...	79	99.	50.4	68.8	35.3	14.6	19.6	23.8	26.8	12.8	18.5	37.4	33.4	18.7
1872...	61.8	67.8	46.0	177.3	33.8	34.8	2.6	13.5	27.0	45.7	47.4	35.3	35.5	19.2
1873...	72.9	64.8	97.8	226.4	82.2	119.1	15.1	19.5	29.8	33.4	40.9	67.9	59.8	24.2
1874 ..	120.0	75.5	154.7	50.2	81.7	40.8	30.0	19.1	34.3	50.3	28.4	29.9	54.3	27.6
1875...	5.5	92.8	71.2	97.5	39.9	23.7	7.1	11.2	17.4	24.6	40.5	129.8	38.8	15.3
1876..	59.3	42.4	69.9	129.7	50.9	31.6	8.9	13.3	22.2	24.3	28.1	31.5	40.3	14.2
1877...	37.6	258.9	87.4	100.	54.6	34.8	23.3	19.6	99.8	14.3	38.8	192.6	52.9	20.0
1878...	56.3	66.9	128.6	50.7	200.0	23.2	13.5	12.0	25.8	14.3	34.0	78.8	49.2	14.0
1879...	64.4	76.3	84.5	95.6	117.0	18.6	9.7	14.7	35.0	66.5	24.2	28.9	46.9	20.0
1880...	47.9	55.3	63.3	53.3	22.2	4.5	4.7	6.1	14.3	16.6	48.9	23.8	28.7	8.3
1881 ..	21.5	50.3	118.1	104.8	39.6	27.0	5.8	7.6	10.8	6.4	21.8	36.7	39.8	7.4
1882...	31.0	75.9	133.	49.3	32.8	33.1	1.7	6.2	10.5	37.9	62.4	42.3	37.4	12.1
1883...	29.2	44.3	115.8	73.1	31.9	3.7	0.6	18.6	47.4	11.5	20.0	29.8	32.4	13.3
1884...	41.8	47.4	103.9	105.1	47.5	17.3	5.9	13.6	14.9	13.1	26.7	34.2	42.2	10.8
1885...	36.1	50.2	202.7	63.6	46.7	14.4	.0	4.8	15.5	15.0	39.0	70.7	35.7	8.8
Ave. 23 years.	48.6	63.5	80.2	80.5	48.5	26.8	12.3	15.7	22.3	20.9	31.0	46.6	40.9	17.4
Av. last 11 yrs.	37.9	61.1	97.0	83.1	48.3	22.0	7.6	11.1	19.2	17.5	33.6	49.7	40.9	13.2

RAINFALL, RAINFALL COLLECTED AND PER CENT. COLLECTED ON THE SUDBURY RIVER WATER-SHED.

Rainfall in Inches.

YEAR.	Jan.	Feb.	Mar.	Apr'l	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Tot'ls	4 mos. July-Oct.
1875........	2.42	3.15	3.74	3.23	3.56	6.24	3.57	5.53	3.43	4 85	4.83	0 94	45.49	17 38
1876........	1.83	4.21	7.43	4.197	2.763	2.040	9.134	1.720	4.614	2.241	5.764	3.620	49.563	17.709
1877........	3.216	0.739	8.357	3.435	3.702	2.425	2.951	3.682	0.323	8.515	5 803	0.870	41.018	15.471
1878........	5.632	5.973	4.689	5.790	0.956	3.884	2.971	6.937	1.291	6.417	7.024	6 367	57.931	17.616
1879... .. .	2.478	3.562	5.140	4.716	1.579	3.789	3.933	6.509	1 878	0.869	2.682	4.344	41.419	13.129
1880........	3.566	3.980	3.315	3.105	1.836	2.138	6.273	4.008	1.603	3.740	1 785	2.828	38.177	15.624
1881	5.558	4.646	5.730	2.000	3.511	5.395	2.35	1.358	2.617	2.955	4.091	3.958	44.169	9.280
1882........	5.951	4.546	2.649	1.824	5.066	1.664	1.769	1.667	8.741	2.074	1.147	2.296	39 394	14.251
1883...	2.81	3.865	1.78	1.845	4.185	2.40	2.68	0.735	1.52	5.60	1.81	3.55	32.78	10.535
1884.	5.085	6.545	4.72	4.405	3.47	3 445	3.665	4.65	0.855	2.48	2.645	5.17	47.135	11.650
1885........	4.71	3.865	1.07	3.605	3.485	2.865	1.425	7.185	1.425	5.095	6.095	2.72	43.515	15.13
Averages	3.932	4.099	4.42	3.469	3.100	3.299	3.702	4.000	2.572	4.070	3.970	3.333	43 986	14.314

RAINFALL COLLECTED IN INCHES.

YEAR.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Tot'ls	4 mos. July-Oct.
1875........	0.184	2.411	2.862	5.263	2.119	1.501	0.573	0.706	0.358	1.152	2.248	1.041	20.418	2.789
1876........	1.147	2.282	7.911	5.683	2.031	0.383	0.326	0.723	0.318	0.417	1.878	0.809	23.908	1.784
1877........	1.174	1.529	8.586	4 132	2.482	1.031	0.360	0 216	0.103	1.127	2.417	2.300	25.487	1.806
1878........	3.228	3.972	6.256	2 807	2.487	0.873	0.229	0.848	0.277	0.921	2.922	5.667	30.487	2.275
1879........	1.249	2.756	4.156	5.379	1.987	0.713	0.281	0.705	0.243	0.126	0.355	0.825	18.775	1.355
1880........	2.048	3.057	2 513	2.069	0.940	0.310	0 322	0.217	0.142	0.186	0.363	0.320	12.487	0.867
1881........	0.729	2.455	7.038	2.630	1.686	2.276	0.486	0.260	0.336	0.326	0.672	1.363	20.257	1.408
1882.... . .	2.181	3.816	4.991	1.476	2.271	0.900	0.152	0.097	0.522	0.526	0.356	0 553	17.841	1.297
1883	0.588	1.640	2.832	2.295	1.618	0.511	0.203	0.138	0.155	0.326	0.348	0.340	11.024	0.822
1884........	1 751	4.673	6.654	4 851	1.811	0.708	0.393	0.452	0.074	0 146	0.298	1.626	23.446	1 065
1885........	2.17	2.149	2.761	3.088	2.348	0.724	0.108	0.422	0.208	0.590	2.003	2.063	18 637	1.328
Averages	1.495	2.794	5 142	3.607	1.981	0.903	0.313	0.435	0 218	0.531	1.263	1.538	20.259	1.527

PERCENTAGE OF RAINFALL COLLECTED.

YEAR.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Y'rly.	4 mos. July-Oct.
1875........	7.6	76.5	76.5	162.9	59.5	24 0	16.0	12.8	10.4	23.8	46.5	110.7	44.9	16.0
1876........	62.7	54.2	106.5	135.4	73.5	18.8	3.6	42.0	6.9	18.6	32.6	22.3	48.2	10.1
1877	36.5	206.9	102.7	120.3	67.0	42.5	12 2	5.9	31.9	13.2	42.2	261.4	57.9	11.7
1878........	57.3	66.5	133.4	48.5	260.2	22.5	7.7	12.2	21.5	14.3	41.6	89.0	52.6	12.9
1879........	50.4	77.4	80.9	114.1	125.8	18.8	7.1	10.8	12.9	15.6	13.2	19.0	45.3	10 3
1880........	57 4	76.8	75.8	66.6	51.2	14.5	5.1	5.4	8.9	5.0	20.3	11.3	32 7	5.6
1881........	13.1	52 8	122.8	131.5	48.3	42.2	20.7	19.2	12.8	11.0	16.4	34.4	45.9	15.2
1882........	36.6	83.9	188.4	80.9	44 8	54.1	8.6	5 8	6.0	25 4	31.0	24.1	45.3	9.1
1883..	20.9	42.4	159.1	124 4	39.4	21.3	7.6	18.8	10.2	5.8	19 2	9.6	33 6	7 8
1884........	34.4	71.4	141.0	110.2	52.2	20.6	19.7	9.7	8.7	5.9	11.3	31.4	49 7	9.1
1885........	46.1	55.6	258.3	85.7	67.4	25.3	7.7	5.9	14.4	11.6	32.9	75.9	42.8	8.8
Averages	38.0	68.1	116.3	104.0	63.9	27.4	8.5	10.9	9.6	13.0	31.8	46.1	46 0	10.6

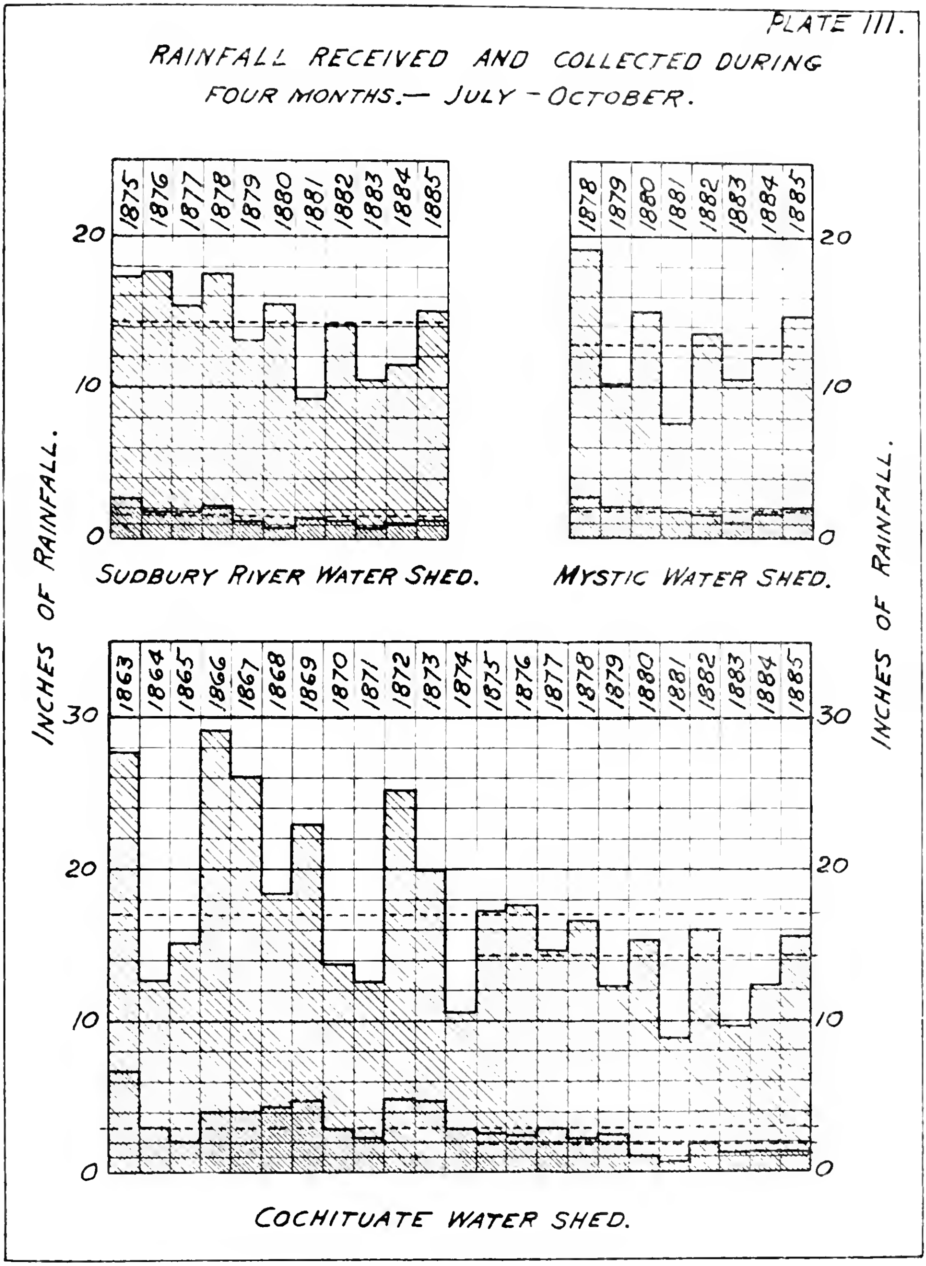
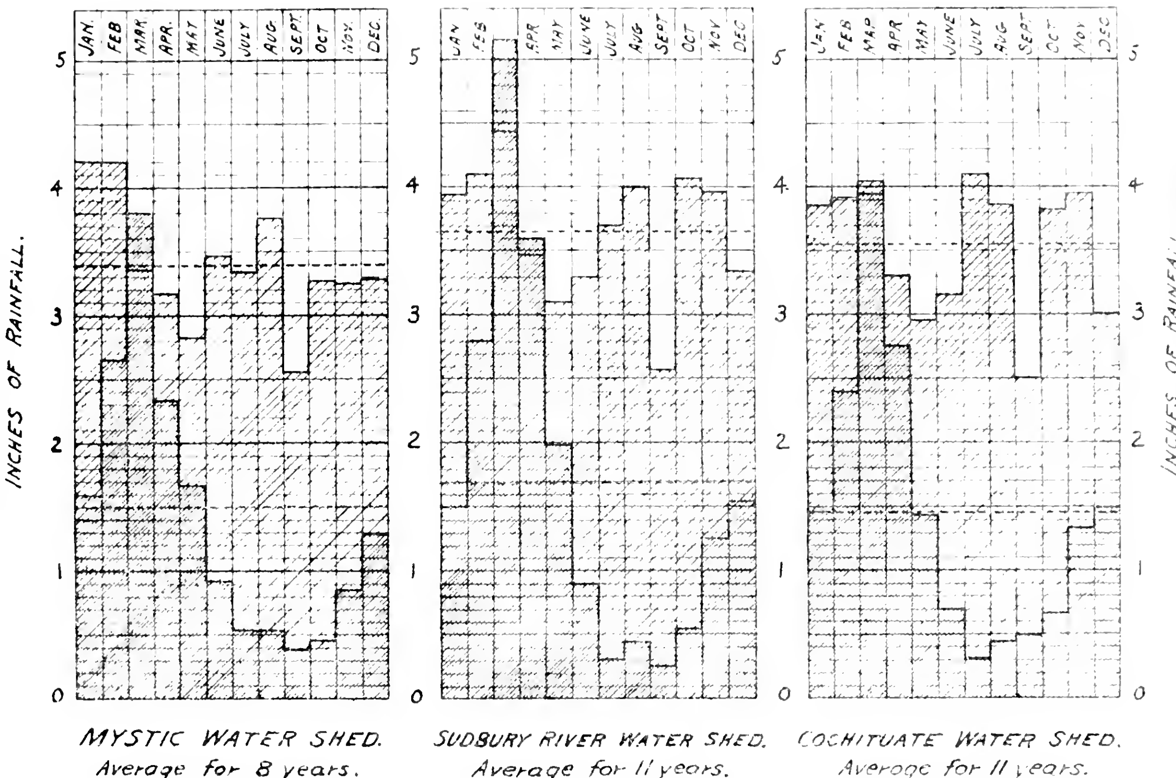


PLATE III.
RAINFALL RECEIVED AND COLLECTED DURING FOUR MONTHS.— JULY – OCTOBER.
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
20
10
0
SUDBURY RIVER WATER SHED.
1878
1879
1880
1881
1882
1883
1884
1885
20
10
0
MYSTIC WATER SHED.
INCHES OF RAINFALL.
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
30
20
10
0
INCHES OF RAINFALL.
COCHITUATE WATER SHED.

PLATE IV.

AVERAGE MONTHLY RAINFALL RECEIVED AND COLLECTED.



TABLES SHOWING RAINFALL, RAINFALL COLLECTED AND PERCENTAGES COLLECTED ON THE WATER-SHED OF MYSTIC LAKE.

Rainfall in Inches.

Year.	Jan.	Feb	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Tot'ls.	4 mos. July-Oct.
1878........	5.67	5.74	3.93	5.73	0.67	2.62	3.52	7.51	3.19	4.95	5.68	4.845	54.665	19.17
1879........	1.82	2.73	3.52	4.65	1.86	3.98	2.39	5.48	1.60	0.77	2.76	3.74	35.30	10.24
1880........	2.62	1.23	2.49	2.18	2.02	1.49	7.23	3.64	1.42	2.70	1.90	2.50	34.12	14.99
1881........	5.82	3.63	6.69	1.51	2.98	6.84	2.60	0.67	2.17	2.16	3.52	3.29	41.91	7.60
1882........	5.545	1.68	2.49	2.11	4.58	2.09	2.34	1.065	8.35	1.91	1.745	2.23	39.165	13.695
1883........	2.67	3.065	2.22	2.47	3.585	1.635	2.785	0.87	1.195	5.45	1.98	2.995	31.22	10.60
1884........	4.745	6.085	4.255	3.18	2.95	4.635	3.72	4.855	0.70	2.70	2.005	4.56	44.39	14.975
1885........	4.83	3.50	1.175	3.145	3.945	1.11	2.04	5.90	1.425	5.52	6.31	2.10	41.50	14.885
Averages	4.21	4.21	3.35	3.16	2.82	3.46	3.33	3.75	2.54	3.27	3.21	3.28	40.62	12.89

RAINFALL COLLECTED IN INCHES.

Year.	Jan	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Tot'ls.	4 mos. July-Oct.
1878........	3.55	3.97	4.91	2.21	2.16	0.78	0.48	1.11	0.56	0.71	1.75	3.63	25.82	2.86
1879........	1.21	2.33	3.31	3.97	1.95	0.97	0.54	0.70	0.48	0.34	0.45	0.69	16.94	2.06
1880........	1.70	2.54	1.95	1.50	0.96	0.51	0.67	0.51	0.45	0.36	0.14	0.59	12.21	2.02
1881........	0.82	2.14	6.79	2.17	1.51	2.05	0.87	0.35	0.31	0.29	0.50	0.87	18.67	1.82
1882........	1.37	3.03	4.19	1.16	1.85	0.81	0.35	0.22	0.53	0.58	0.39	0.57	15.05	1.68
1883........	0.70	1.13	1.88	1.63	1.20	0.52	0.30	0.22	0.18	0.39	0.42	0.14	9.32	1.09
1884........	1.49	3.89	5.42	3.85	1.48	0.85	0.58	0.60	0.23	0.27	0.35	1.17	20.18	1.68
1885........	1.79	1.81	2.05	2.63	2.18	0.86	0.47	0.54	0.34	0.68	2.41	2.39	17.55	2.03
Averages	1.58	2.64	3.81	2.32	1.66	0.92	0.53	0.53	0.38	0.45	0.85	1.29	16.96	1.89

PERCENTAGE OF RAINFALL COLLECTED.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Y'rly.	4 mos. July-Oct.
1878........	62.6	69.2	125.0	38.6	322.9	29.6	13.5	14.8	17.7	14.3	30.8	71.9	47.8	14.9
1879........	66.6	85.4	93.9	85.3	101.9	24.5	22.6	12.8	29.7	44.2	16.2	18.6	48.0	20.1
1880........	64.9	60.1	78.4	68.8	47.3	34.3	9.2	14.7	31.7	13.5	22.9	23.8	35.5	13.5
1881........	14.2	58.9	101.5	141.1	50.7	29.9	33.3	51.9	14.1	13.6	14.3	26.3	44.5	23.9
1882........	24.8	64.8	168.1	55.0	40.4	38.6	14.9	20.8	6.3	30.0	22.2	25.5	38.4	12.3
1883........	26.1	46.7	81.8	65.9	33.5	31.8	10.8	25.7	12.1	7.2	21.1	14.7	29.8	10.3
1884........	31.5	63.9	127.3	121.2	50.2	18.3	15.5	12.4	33.5	9.9	17.4	25.6	45.5	14.0
1885........	37.1	53.3	174.5	58.8	55.3	19.6	22.8	9.2	23.7	12.2	38.2	113.6	39.4	13.6
Averages	37.5	62.7	113.7	73.4	58.8	26.6	15.9	14.1	15.0	13.8	26.2	39.3	41.75	14.7

The yearly rainfalls and amounts collected are shown graphically by the profiles on Plate 1, and show to the eye much better than figures the fluctuations in the quantities from year to year. It will be noticed that the rainfall during the past 12 years has been much below the average; the Lake Cochituate average for the last 11 years being 5.37 inches less than that of the past 34 years. The rainfall collected has also fallen much below the average, and the years 1880 and 1883 show on all of the profiles quantities much smaller than any previous records.

The profiles on Plate 2 show the percentages collected on the different supplies, the upper profile showing the percentage collected during the year, and the lower profile the percentage collected of the rainfall of the

four months, July to October. It will be noticed that the years 1880 and 1883 were not only years of small rainfall, but that the percentages collected were also below the average; the average percentage collected on the three water-sheds being about 33 per cent. for each of those years.

The rainfall during the summer and autumn varies but little from that of the winter and spring, but the percentage which can be collected during the former period is very much smaller. The average amounts during these periods, for the time covered by the preceding tables, have been as follows:

	June to November inclusive.		December to May inclusive.	
	Rainfall. Inches.	Rainfall coll. Inches.	Rainfall. Inches.	Rainfall coll. Inches.
Lake Cochituate......	21.37	3.91	21.08	13.45
Sudbury River.......	21.613	3.693	22.353	16.557
Mystic Lake..........	19.59	3.66	21.03	13.30
Averages...........	20.858	3.754	21.488	14.436

From July 1 to November 1 the percentage of the rainfall which can be collected is very small, as will be seen from an inspection of Plates 2, 3 and 4. The line of average monthly rainfall on Plate 4 shows a marked depression during the month of September on all of the profiles. This irregularity in the profile would partly disappear if the observations covered a longer period, but the month of September is generally one of small rainfall. A comparison of the upper and lower lines of the profile shows very clearly the fact that a very large proportion of the rainfall collected during the year is collected during the months of February, March and April, and that while the average monthly amount collected for the year is about 1.50 inches, there are seven months when the amount is less than the average, and four months when the amount is only about 0.50 of an inch per month. It is very evident, therefore, that in order to make available the average yield of any water-shed, reservoirs must be provided to store the rainfall collected during the spring months.

From the fact that during the years 1880 and 1883 the records of all the supplies show that only between ten and eleven inches of rainfall were collected in the streams and ponds, it is evident that it is not safe to assume a collection of more than ten inches in a year of extreme drought. That this is a smaller amount than has been generally used by engineers in estimating the value of water supplies in this section of the country is shown by the following estimates made by different engineers: W. J. McAlpine in 1870 made a report on the water supply of Lynn, in which he estimated that each square mile of water-shed would furnish one million gallons daily, and stated that "this quantity is regarded as a perfectly safe amount, and will more frequently exceed than fall short of the actual quantity."

J. P. Kirkwood and J. B. Francis, in a report on the Mystic supply in 1873, assumed that fifteen inches of rainfall might be collected from the Mystic Basin during the dryest year.

Joseph P. Davis, in estimating the value of different supplies in the vicinity of Boston, based his calculations on a minimum yield of twelve inches of rainfall.

H. P. W. Birkenbine, in considering the water supply of Lebanon, Pa., believed that a safe estimate of the available rainfall was from 46 to 50 per cent. of the yearly rainfall.

In a report on the supply of Manchester, N. H., in 1869, J. B. Sawyer calculated upon a collection of 14.33 inches in a year of drought. A report on the supply of Newton, made in 1872, by Edward Sawyer, the safe collection in a very dry year is estimated at 15 inches.

That these estimates were so much larger than later results show to be safe may be considered as owing to the fact that careful observations of the rainfall collectable have not been more generally recorded on the water supplies of the county. It is to be hoped that in the future more attention may be given by members of our profession to this branch of the question of water supply engineering.

THE IMPROVEMENT AND DRAINAGE OF THE SPICKET RIVER VALLEY, LAWRENCE, MASS., 1883-1886.

BY ARTHUR D. MARBLE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read June 16, 1886.]

The city of Lawrence is located about twenty-six miles in a northwesterly direction from Boston and nine miles below Lowell, on the banks of the Merrimack. Nestled in a little valley between two hills which rise, one on the east and the other on the west, to a height of 150 feet above the general level of the heart of the city. But little over forty years ago, only an old-time farm-house here and there dotted the quiet landscape, furnishing the only sign of civilized life in the neighborhood.

Fortunately, one of the farmers located here had been a manufacturer, and, in his mind, the thought came of great possibilities in Bodwell's Falls, located within the present limits of the city, and in Peters' Falls above. These he measured with a straight-edge and level, and with his idea matured, he presented the case to certain capitalists, of whom the Lawrence family were prominent.

The thought and enterprise of this farmer-engineer were the introduction to the present great dam which chains the rolling waters of this "river of uses," as one of our historians calls it, to the canals, the monster mills, the busy spindle and the flying shuttle, which furnish employment for thousands of hands and make the city of Lawrence. To the river we owe our birth as a town and city, and to it our continued existence. From it we take the water for domestic use, freighted though it may be with the sewage of Lowell, of Nashua, of Manchester and Concord, and into it we in turn discharge our own sewage, yet a short distance below the city the water seems as pure as when it flowed from the great lake in the midst of the New Hampshire hills. On our southeastern border runs the Shawsheen, which Boston is so anxious to divert from its ancient channel and turn into the sea at Moon Island. Through the northern portion of the city, about midway between the Merrimack and our northern boundary line, runs another stream about the same size as the Shawsheen, called the Spicket For

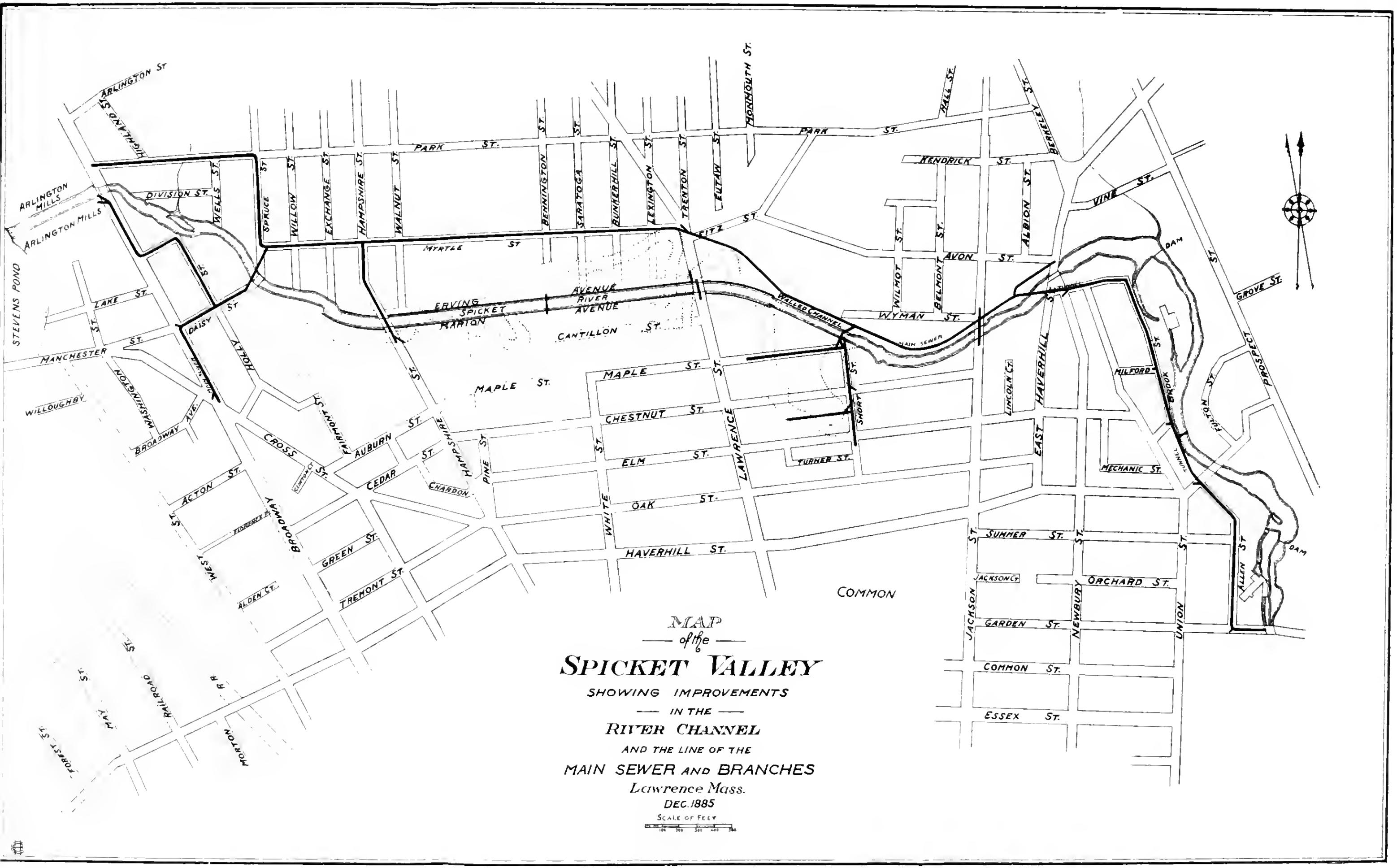
a mile it runs nearly parallel with the Merrimack, and then turns to the south and discharges into it, about three hundred feet above the mouth of the Shawsheen.

This Spicket river is comparatively small, yet it drains a number of ponds which act as reservoirs and render the supply quite regular and continuous, making the river available for water-power at Methuen village, where are located various manufacturing interests; and soon after crossing the Methuen line another dam furnishes power to the Arlington mills, and still further down the river two other dams obstruct its flow, one at a shoddy mill aud the other at a worsted mill. Between the Spicket river and the Merrimack is the most populous part of the city, and the centre of density of population is rapidly extending north toward the Methuen line. Into the Spicket discharged the first sewer built by order of the municipal authorities, and up to the summer of 1883 twenty-four different sewer outlets from the thickly-settled part of the city made a constant contribution of filth to the stream, which was further polluted and badly discolored by the sewage from the jail aud the entire drainage of the Arlington mills, including the dye-house, from which came ingredients which blackened the water when the flow in the river was limited. Another source of trouble were the two dams near the mouth of the river, which made the current too sluggish to hold in suspension the sewage which was discharged into it. The river usually got a scouring out once or twice each year in the spring and fall freshets, but at times during the summer months the volume of flow is very small, and at such times the complaints came from its neighborhood of offensive odors from the exposed banks saturated with the filth deposited during more than a quarter of a century, and from seventeen acres of sewage-polluted water surface.

The citizens and City Council agitated the question of improving the valley for two years, and in 1882 a petition was presented to the Legislature resulting in the passage of an act authorizing the city to improve and straighten the river channel, to build the necessary sewers, to take real estate, to cause private land to be filled, and to delegate the carrying out of the work to a board of commissioners. In the spring of 1883 three commisioners were appointed. The river and valley were examined by them during the summer of 1883; a report presented to the city government with suggestions, plan and estimate of cost, which were adopted by the city council, and work was commenced on the main sewer in October, 1883. The improvements were instituted and the expenses of them allowed by the Legislature solely on the pretext of the public health. It is an open question whether any individual sickness had been caused by the condition of the river, and we have had no serious epidemic; but the danger threatened, and the people demanded the remedy which has been applied.

The improvments may be divided into two parts: first, the construction of a main sewer into which now discharge all the city sewers previously discharging into the river; and second, the straightening of the river channel and the grading of the low territory adjoining.

In 1876 our honored vice-president prepared a sewerage plan for the


MAP
of the
SPICKET VALLEY
SHOWING IMPROVEMENTS
IN THE
RIVER CHANNEL
AND THE LINE OF THE
MAIN SEWER AND BRANCHES
Lawrence Mass.
DEC. 1885
SCALE OF FEET
ARLINGTON ST
HIGHLAND ST
ARLINGTON MILLS
DIVISION ST
WELLS ST
SPRUCE ST
WILLOW ST
EXCHANGE ST
HAMPSHIRE ST
WALNUT ST
PARK ST
BENNINGTON ST
SARATOGA ST
BUNKERHILL ST
LEXINGTON ST
TRENTON ST
EUTAW ST
MONMOUTH ST
HALL ST
KENDRICK ST
BERKELEY ST
VINE ST
ALBION ST
AVON ST
WILMOT ST
BELMONT ST
WYMAN ST
FITZ ST
MYRTLE ST
STEVENS POND
LAKE ST
DAISY ST
MANCHESTER ST
WILLOUGHBY
WASHINGTON
BROADWAY AVE
HOLLY
CROSS ST
FAIRMONT ST
ERVING AVENUE
SPICKET RIVER
BARTON AVENUE
CANTILLON ST
MAPLE ST
WALLED CHANNEL
MAIN SEWER
SHORT ST
CHESTNUT ST
ELM ST
TURNER ST
OAK ST
HAVERHILL ST
LAWRENCE ST
WHITE ST
PINE ST
CHARDON
AUBURN ST
CEDAR ST
ACTON ST
BROADWAY
WEST ST
ALDEN CT
GREEN ST
TREMONT ST
RAILROAD
MAY ST
FOREST ST
MORTON
COMMON
LINCOLN CT
EAST HAVERHILL ST
MILFORD
BROOK ST
MECHANIC ST
SUMMER ST
JACKSON ST
JACKSON CT
ORCHARD ST
GARDEN ST
COMMON ST
ESSEX ST
NEWBURY ST
UNION ST
ALLEN ST
DAM
FULTON ST
PROSPECT
GROVE ST
TUNNEL

city, and a main sewer of similar design and location was one of its features. We have changed Mr. Rice's original plan to some extent, but the idea remains the same. The main sewer, as now built and completed, is 8,683 feet long and the diameter varies from 5 feet 9 inches at its outlet to 3 feet at its upper end. It still discharges into the Spicket, but at a point below the lowest dam, leaving the flow unobstructed to the Merrimack through a channel with a fall of about three feet in eight hundred. The outlet is under a new bridge, which was being constructed at the same time, and anticipating the time when the discharge from the sewer at that point would prove a nuisance, we made an arrangement under the abutment, by a three-foot sewer, that the sewage could at any time be taken further down the river to near the Merrimack. The section was only completed under the abutment, leaving the extension for the future. The route of the main sewer for 6,183 feet was in the public streets, the remainder through private land. Two sections, one 361 feet long, the other 206 feet long, were tunneled. The character of the tunnel excavation was ledge for the lower half, and sand and gravel, with considerable water, in the upper half. The legs of the bracing rested on a short plank on the ledge. They were of 6 inches by 8 inches spruce timber, and the caps 8 inches by 8 inches spruce, 7 feet 6 inches long. The lagging was 2-inch plank, 5 feet long, sharpened at one end, each section of lagging placed below that already in place, driven two feet, and then a temporary cap supported on a middle leg was put in and the lagging driven the remainder of the length to flush with the face of the cap, and another set of bracing timbers put in 4 feet 4 inches from the first. Where the excavation was very bad, a middle set of bracing was put in.

Height of the tunnel excavation, about 9 feet 6 inches. Drilling in the tunnels was by hand drills. Average cost per lineal foot of tunnel excavation was $14.91 and $12.20 respectively for each section. Aside from the tunnel, we had about 6,000 cubic yards of rock excavation. On this were employed two steam drills during the greater part of the season of 1884, one engine of twenty horse-power furnishing steam for the drills and for running the derrick which was used in hoisting the buckets of material from the trench. For drills we had the Rand and Ingersoll; for explosives, Hecla and Atlas powder. Holes were sunk from 4 to 14 feet deep, according to depth of face. About 50 feet of drilling was an average day's work per drill. Size of drill, 1¼-inch octagon. The rock was almost entirely blue-stone, very shaky. Our experience with the steam-drills was that the Ingersoll was least expensive to maintain, but that the Rand would free itself better and was least liable to get caught in the seams of the rock; 6,721 cubic yards of ledge excavation were removed, at an average cost of $3 per cubic yard. About 1,200 feet of the length of the sewer was in quicksand. For about half this distance we were obliged to use four-inch tongued and grooved plank for the sheet piling. The bottom of the excavation was planked over with two thicknesses of 2-inch plank and on this platform the sewer was built, the entire space between the invert and platform and sheet-piling being filled solid with brickwork. Through the remainder of the quicksand the piling was of 2-inch plank,

and the amount of brickwork governed by the varying conditions. The piling and cross-bracing in the quicksand was nearly always left in place. The depth of the excavation throughout the line of the main sewer was eighteen feet on an average. The planking of the trench was entirely in the form of sheet piling, about 15 feet long and two inches thick for the most part, except as before stated in certain sections of the quicksand. The stringers were 6-inches × 8-inches, and the cross-bracing was 6-inches × 6-inches. The sheet piling was driven by hand; three men running an iron hammer one foot long, seven and one-half inches wide and four inches thick, weighing about one hundred pounds, being employed constantly on each side of the trench in driving. For about one-half the length of the sewer, a second line of sheet piling was driven below the first, and this length was rarely drawn, being cut off about level with the top of the arch. The water was removed from the trench by the use of the Edson diaphragm pump; one and two pumps, according to circumstances, being used constantly in each section of the excavation.

All existing house drains encountered were connected as the work progressed.

The inclination of the sewer is such that when the depth of flow is one-quarter of the diameter, the calculated velocity of flow is not less than three feet per second.

The 5 ft. 9 in. section, and the 5 ft. 6 in. section were laid with three rings of brick, and the other sizes with two rings, with buttresses every four to six feet in the length of the sewer. These buttresses are eight inches wide, extending from the top of the cradle to the spring line of the arch, and built to the side planking of the trench when this was not removed, or to the solid bank. The construction of the sewer being entirely done by the day, there was no inducement for any one to slight the work, but one accident occurred which gave to the city council a pretext for attributing defective and careless work to the commission and their employés. While excavating the sewer trench within about seventy-five feet of the old channel of the river, the water, following as we supposed a musk-rat's hole, suddenly began to run through the bank to the trench. Beginning with a stream about the size of a man's arm, it rapidly increased in volume and in ten minutes the trench and about 1,700 feet of completed sewer were submerged. The sewer was 5 feet 3 inches in diameter, with two rings or 8 inches of brickwork for a shell. The effect on the sewer was to spread the walls of a section recently finished, forming a crack at the crown for a length of about one hundred feet. It was considered serious only for a length of fifty feet where the walls spread about four inches in extreme measurement, and this section was relaid, though had it not been, I think it would have proved stable. The city council held a public sitting of five hours, making of themselves a tribunal, with the mayor as examining attorney for the city, to investigate the cause of the accident. Experts in brick sewer masonry who had previously been through the sewer, were called in and testified finding the work to have been done in a "most thorough and workmanlike manner, and that the materials appear to have been of the best quality." As to the cause of the

break in the sewer, the backfilling around the invert and arch may have been improperly done, or with such material that, mixed with water, it became merely mud and entirely inadequate to resist any sudden pressure. We anticipate that the sudden flood of water acting on the confined air in the sewer may have exerted a sufficient pressure on the green brickwork to cause the rupture. The question arose as to the thickness of the shell of the sewer, whether sufficient or not. The depth of cutting where the break occurred was about twenty-two feet. The eight-inch shell was sufficient at another place with a depth of cutting of thirty feet, but of course another four inches of brickwork would help make up for defective tamping of the earth or improper filling material. The city council could attach the blame to no one, and the work went on without further accident.

The sewer in nearly its entire length was laid on a timber foundation mostly in the form of a cradle of 2 × 4 inch joist laid flatwise. This cradle facilitates the laying of the brick and keeps the brickwork dry in laying. The joist was nailed to a form, and in process of laying the brick this form was removed.

It was impossible to carry the sewer in its entire length on one side of the river, and it became necessary to cross the river twice: first at East Haverhill street, where the original plan provided for an inverted siphon, but by flattening and widening the shape of the sewer the siphon was avoided and the channel of the river is unobstructed. The walls of this section were strengthened by additional brickwork, and covered over the arch with from seven to twelve inches of concrete. The depth of water in the river was reduced about four feet by opening the gates at the dam below, and a sand-bag dam diverted the regular flow of the river to one side of the channel while the sewer was in process of construction. One-half the length was laid at a time.

The sewer crossed the river again at Daisy street, about 900 feet from its upper terminus. Here also the original plan was for an inverted siphon, but we decided to substitute two lines of thirty-inch iron pipe for the brick siphon previously planned, with the grade of the inverts continuous with that of the brick sewer at each end. The two pipes were used to lessen the height of the sewer in order not to obstruct the river channel. To make the passage through the river a dam of puddle clay on each side of the proposed location was made, running half-way across the channel and closed in at the end in the middle of the stream; then two-inch sheet piling was driven around the two sides and end, the water pumped out and the excavation made. The two lines of pipes were laid on a plank platform; they were placed as close together as possible, leaving only sufficient room between them to allow the making of the joints, which were run with lead. After the pipes were laid, gravel was packed around them, the sheet piling cut off about level with their top, and with the water drawn down as low as possible, the earth constituting the dam was removed. One-half of this line of pipe was laid on one Sunday, and the other half the next.

In carrying out the plan some 7,000 feet of branch sewers have been constructed, mostly for the purpose of connecting the old sewers, which previously discharged into the river, with the new main sewer. One branch

runs to the Arlington mills, from which it is proposed to take the entire polluted discharge. Arrangements have not yet been made with the corporation, and I anticipate they will resist any attempt on the part of the city to oblige them to drain their dye-house into the sewer.

Nearly all the old sewer outlets have been retained as overflow sewers, the new main being capacitated to take $\frac{1}{10}$th of an inch of rainfall over 711 acres of the area drained, $\frac{1}{50}$th over 181 acres, and ⅛ of an inch over the remainder, making a total of 972 acres. The connections between the old sewers and the main are very simple, consisting for the most part of 6-inch and 8-inch pipe in short distances, running from a man-hole on the old sewers, in which was built a low dam to divert the sewage to the pipe, leaving the old outlet to serve as an overflow. The connection between one of the old sewers and the main had to be made across the river channel at a point where the main sewer was too high to allow the pipe to be laid beneath the bed of the river and allow of a continuous incline to the main, and we constructed the section under the channel in the form of an inverted siphon of 8-inch iron pipe. The siphon is 90 feet long and the dip 4 feet 9 inches. At its upper end is a settling basin 5 feet deep, and through the pipe is run a chain with which to free the pipe if it should get clogged. One other connection was through a bridge above the water. This connection consisted of a 6-inch iron pipe encased in a 12-inch iron pipe, forming an air space around the sewage pipe to prevent freezing. It is situated in a very exposed position, but it worked perfectly all this last winter, and we anticipate no trouble from it. A copper wire is run through this pipe with which to free it of obstructions, should there ever be any.

We were obliged to lay four other connections under the river ; three of these occurred in the new channel, and were laid before the water was let in. Two were of iron pipe and one of Akron arched with brick. The fourth was also of iron, was laid in the old river channel, and under considerable difficulty, taking advantage of low water on Saturday night and Sunday. Here also a sand-bag dam was used, but the water flowed over the dam before the work was entirely finished, driving the laborers out, and the water has not been low enough since to allow the finishing of the job. The brick used were mostly from Plaistow, and cost on the works in Lawrence an average of $7.15. Number of brick used up to January 1st, 1886, 3,375,000. We used the F. O. Norton brand of cement, costing $1.43 per cask, by contract with a local dealer. Cement was mixed in proportion of 1½ sand to 1 of cement, using an average of 2½ casks per 1,000 brick. The average cost of the brickwork laid was $15.75 per 1,000, or $9.27 per cubic yard.

The straightening of the old channel of the river was not considered of first importance ; but carrying with it, as it does, the grading of all the low lands adjoining, making high ground of what had been little better than marsh land, the straightening becomes an important factor in this line of improvements instituted for the benefit of the public health. No one can deny the great improvement in the appearance of the locality with the straight channel and fine bridges which span it. With the exception of the pumping station and reservoir of the water works, it forms the most attractive feature of municipal work accomplished for

many years. The width of the new channel at the bottom is 34 feet, and the sides, which slope two to one, are paved to the depth of 15 inches with field stone. Through a section where the cutting was about 17 feet, the channel was walled for a distance of about 468 feet, the wall being built to within about 6 feet of the surface of the ground, and of a size sufficient to allow of its extension to such a height as may be established as grade for the proposed avenue adjoining. The distance between the walls is 50 feet, measured between points 3 feet above the grade of the bottom of the channel, being at a point about half the depth of water at its ordinary dry weather height. The walls were built by contract. They are of rubble stone, laid dry, with the exception of the face, which was laid to a depth of 1 foot with cement mortar. The prices were $3.25 for dry and $5 per perch for mortar-work. The excavation of the next section of the channel through a boghole for a length of 153 feet, with sloped banks, was also done by contract at 55 cents per cubic yard, against 31½ cents for the section that was walled. The remainder of the channel excavation was done by the Spicket department with its own teams, and the expense was 32 cents per cubic yard. The paving was also done by the city, at a cost of $32\frac{7}{10}$ cents per perch for laying, the stone costing 90 cents per perch delivered on the ground. As the land adjoining the new channel is further improved by grading, the river bank will have to be raised, and the plan is to increase this height by a low stone wall built along the top of the slope. The filling material for the old channel has been delivered on the ground by several contractors, costing the city 30 cents per yard, the length of haul being about a mile. The city took care of the dump, at an additional expense of about 2 cents per yard. The ordinary depth of water in the river channel is 6½ feet, being practically still water, held back by the dam below, the surface velocity with the water at ordinary stage being about one-third of a foot per second. The width of the channel with sloped banks when the water stands level with the top of the dam is about 58.4 feet. An avenue is to run on the north and south banks of the new channel, along which trees are to be planted, the whole intended to form, when completed, a sort of park, having a length of about 3,000 feet and a width of 180 feet. Further straightening of the channel above the terminus will follow these improvements about completed, and with the bushes and weeds, which have collected all manner of floating filth, kept from growing along the water's edge, the river will no longer be a source of sanitary uneasiness. The length of the new channel is 3,050 feet, displacing a length of 7,250 feet of old channel. Area of the old channel from the Arlington mills to the next dam below is 16⅝ acres, while the area of the new channel is but 9⅞ acres, being a reduction of about 7 acres of water surface. The section of the river on which these improvements were made formed the mill pond of Tower, Wing & Co., manufacturers of shoddy, and they have brought two suits against the city, one for polluting the stream before the improvements were made, the other for lessening the storage capacity of their pond. It is understood they claim about $20,000 damages.

No regular records have been kept of the flow of water in the river.

but the amount for the year ending Sept. 1, 1885, was such that for seven months the Arlington mills used about 137 cubic feet of water per second, for three months about 77 cubic feet per second, and for the remaining two months about 60 cubic feet per second, giving a fair idea of the value of the stream.

Two iron bridges have been constructed over the new channel. The character of the excavation for the foundation of the abutments was sand, intermixed with vegetable earth, being a deposit of the Spicket river, brought down from the northern hills and meadows in prehistoric freshets. This was easily removed, requiring little or no use of the pick. At a depth of from four to six feet below the grade of the channel the vegetable earth disappeared, and the foundations were put in. These consisted of platforms of solid timber, ten feet to twelve feet wide, sixty-five or more feet long, and from sixteen to eighteen inches in thickness. First, a flooring of planking was laid lengthwise of the abutment: on this, heavy timbers were laid close together across the line of the abutment, and floored again on top of the timbers with planking. The lumber used was well seasoned, perfectly sound and free from sap. On top of the timber-work were laid the broad stone levelers, many of them covering an area of fifty square feet. Upon this foundation, which was brought to the grade of the new channel, and which had a surface of about 700 square feet, was raised the abutment with a base about eight feet broad, battering on the face and back to about five feet wide at the level of the truss-seat, nine and one-half feet above the levelers. Above the truss-seat runs the parapet wall five feet and one-half high, capped with flagstone two feet wide and eight inches thick. The masonry is rubble, with bearing stones of granite for the trusses. Face of the abutments laid in mortar one foot deep from the face; remainder of the abutment laid dry.

The bridge at Hampshire street was the first built. It does not stand square with the line of the stream, but at an angle of 62° 30′. The length of the trusses, from centre to centre of end-pins, is 61¼ feet. The roadway is 30 feet wide between trusses, and the sidewalks each 7 feet wide in the clear. The roadway is designed to carry a moving load of 100 lbs. per square foot of surface and the sidewalks 80 lbs. The floor timbers are Southern pine, the roadway, which is crowned 3 inches continuously through the length of the bridge, being planked with two thicknesses of two-inch Southern pine plank, tarred between the courses, the upper planking running with the line of travel, and the whole roadway is covered with roofing tar and gravel. The sidewalks are planked with a single thickness of two-inch Southern pine plank, and are protected with a substantial iron fence. Though not entirely finished, the bridge was opened for travel June 25, 1885, just two months from the time the ground was broken for the foundations. Cost of the bridge and abutments complete, $6,400.

Plans were made for a stone arch bridge at Lawrence street, but owing to the excessive cost the plan was abandoned and an iron bridge was erected instead. This also does not stand square with the line of the channel, but at an angle of 80°. The length of trusses from centre to centre of end-pins is 56 feet 8 inches. The roadway is 40 feet wide,

crowned 4 inches continuously between the trusses, and each sidewalk is 8 feet wide in the clear, the street at each end of the bridge being 60 feet wide. The cost was about $9,100. The estimated cost for the stone arch was about double this amount.

The Boston Bridge Works had the contract for the iron-work, and constructed the bridges in their usual superior manner.

The city has acquired, by seizure of the old river channel discontinued and of lands demanding filling or necessary for the use of the city in the construction of these public works, some 31¼ acres. This is to be laid out in streets and lots and sold. Settlement has been made for a part of the land damages, and part will be settled by the courts. A number of wells were drained in the construction of the sewer. The owners petitioned for damages, and the commissioners settled all by connecting the different houses with the city water. Each well cost the city an average of about $11, but the city in turn will receive a constant revenue from the parties for the use of the water.

In conclusion, I desire to say that the success of the construction of the works is largely due to Mr. S. J. Edwards, our efficient superintendent, who immediately previous to his employment in Lawrence was in charge of sewer construction in Lowell, and is now at Lynn in the employ of Mr. McClallan, constructing the new main sewer in that city, a work which, as is well known, has proved quite a serious undertaking. The financial affairs were managed by the commission, at whose head was Mr. A. A. Lamprey, to whose careful management is largely due the fact that the work has been completed at about the amount of the original estimates. This is particularly gratifying from the fact that with the exception of a small part mentioned previously, and the furnishing of the filling material, all the work has been done by the day, with help employed by the superintendent, under the direction, to some extent, of the commission.

DESCRIPTION OF PLATES.

Plate I.—Nos. 1, 2, 3, 4 represent sections of the main sewer. No 1, taking the place of the originally proposed siphon at East Haverhill street.

Nos. 5 and 6, sections of two branch sewers.

No. 7, section of the wall built along the new channel, where the depth of excavation was about 16½ feet. Wall will in time be extended in height from three to four feet.

Nos. 8 and 9 show profile and section of the Akron pipe sewer under the new channel.

No. 10 shows the siphon on one of the branches.

No. 11, another branch sewer connection under the river channel.

No. 12, abutment of Hampshire street bridge.

No. 13, manner of bracing the tunnel.

Plate II.—Nos 1, 2, 3 represent the man-hole near the outlet of the main sewer, where the sewage is to be diverted from the present outlet and carried further down stream.

Nos. 4, 5, 6, the twin iron pipe sewer under the river at Daisy street, taking the place of the siphon originally proposed.

Nos. 7, 8, a man-hole on a branch sewer, showing the eight-inch sewage pipe in the left-hand corner, and the overflow sewer above.

Nos. 9, 10, 11, man-hole at upper terminus of the main sewer.

FOUNDATIONS OF THE GARFIELD MONUMENT.

By James Ritchie, Member of the Civil Engineers' Club of Cleveland.

[Read April 13, 1886.]

It is not my intention to describe in detail the construction of the Garfield Monument, but simply to present a few facts as to the foundations and the stone used in construction, to the members of this Club. The foundations have already been laid, and the dimensions are approximately as follows: Length, east and west, 70 feet; width, north and south, 51 feet; inside diameter of tower, 40 feet; thickness of tower walls at base, 4 feet 6 inches; height of tower above ground, 225 feet; thickness of walls at foot of corbeling near top of tower, 2 feet 6 inches. The pressure of the outside tower walls alone upon the lower course of the foundation will be about 8 tons per square foot, and the additional pressure from force of wind about 1½ tons per square foot, assuming a wind force of 50 pounds per square foot of surface exposed. This gives a total upon the lower course of masonry of 9½ tons per square foot. The limit usually adopted for Berea stone is 10 tons per square foot, hence there is no danger of the masonry being crushed by the weight above. The pressure of the foundations upon the ground below was not figured, as I had no means of finding the actual extent of the bearing or footing courses.* The preparation of the foundation soil should have had the greatest care. The surface soil, which has a depth of from three to five feet, is almost entirely yellow clay. Beneath this is a substance known as *shale*. It is very easily acted upon by the elements, and should, therefore, be carefully examined for traces of such action. These traces are easily discerned by any visitor to the site of the monument. A roadway has been excavated completely around the site, and from 100 to 200 feet from the monument. This has made necessary an excavation of from 1 to 14 feet in depth, which has exposed the edges of the strata of shale for a depth of from 1 to 10 feet. The strata dip toward the southeast at an angle of about 10° with the horizon, and the surface of the ground falls off toward the northwest with a grade of about 1 foot in 12 feet. Immediately after a rain, water may be seen oozing out between the clay and shale along the banks of the roadway. This is gradually undermining the clay, and tends to produce motion of the surface soil upon the underlying stratum, as well as to wear away the surface of the shale.

All this goes to show that the foundations of a building which should last forever are being placed upon or in a substance which is, to say the least, unreliable, and easily disintegrated by the action of the elements. We all know that in this latitude frosts *have* penetrated to a depth of fully six feet. Wherever the frost has been there will have been

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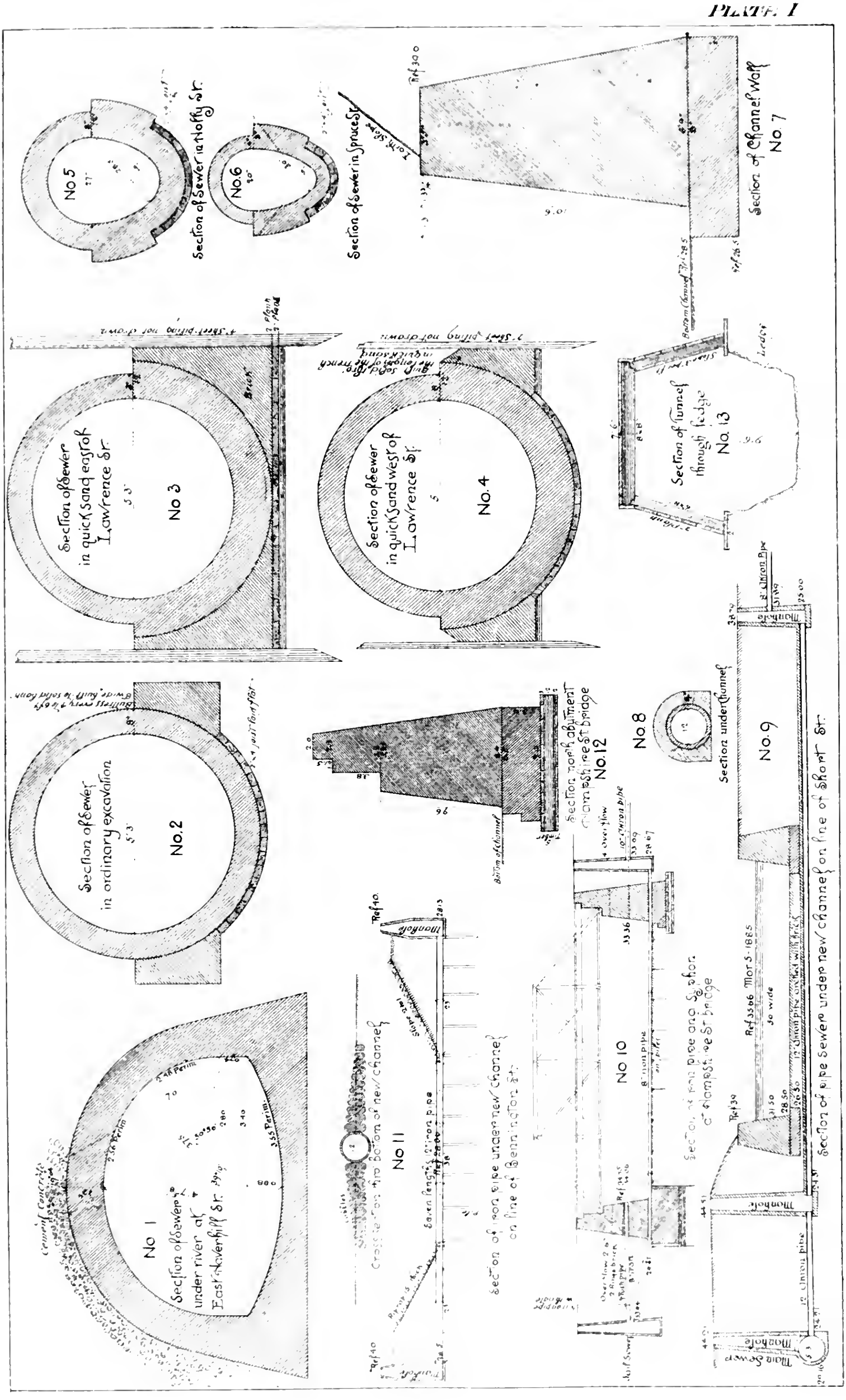
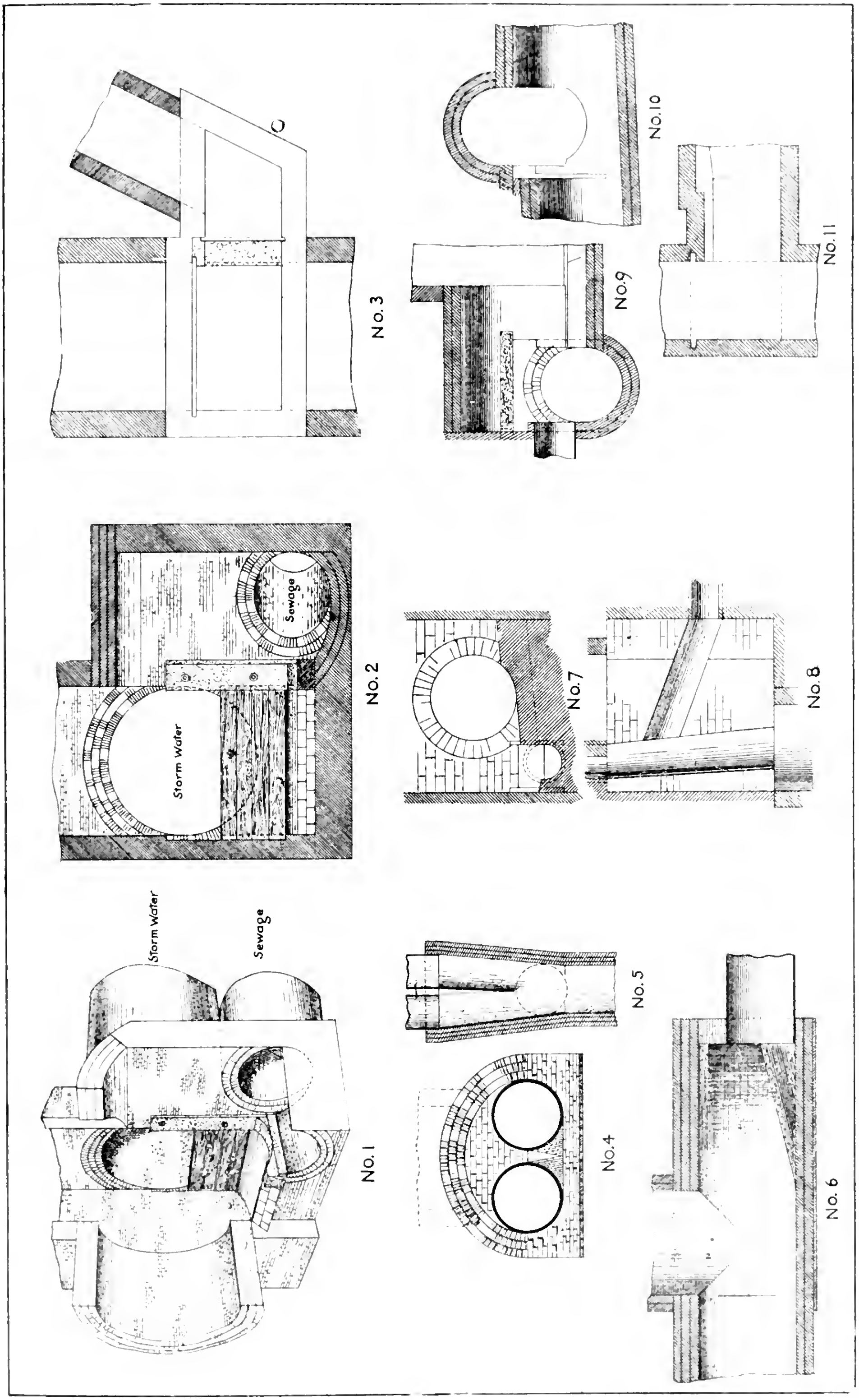
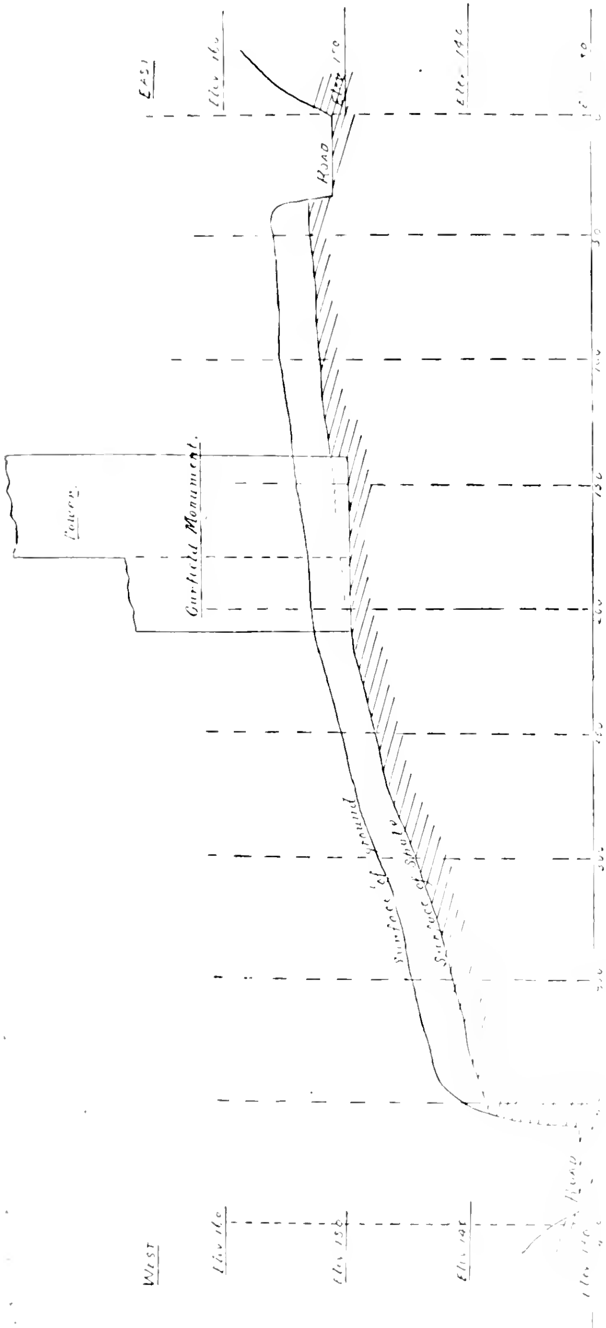
* The pressure upon the *clay* has since been found by Mr. W. H. Searles, C. E. to be 11½ tons under inside walls and 6 tons under outside walls per square foot.—J. R.


No 1
Section of Sewer under river at East Haverhill St.
Cement Concrete
No. 2
Section of Sewer in ordinary excavation
No 3
Section of Sewer in quick sand east of Lawrence St.
No. 4
Section of Sewer in quick sand west of Lawrence St.
No 5
Section of Sewer in Hoffy St.
No. 6
Section of Sewer in Spruce St.
Section of Channel Wall
No. 7
No. 8
Section under Channel
No. 9
Section of pipe sewer under new channel on line of Short St.
No 10
Section of iron pipe and Syphon at Hampshire St bridge
No 11
Cross section thro bottom of new channel
Section of iron pipe under new channel on line of Bennington St.
No. 12
Section north abutment Hampshire St bridge
Section of Tunnel through ledge
No. 13
Main Sewer
Manhole
Ref 35.66 Mar 5-1885
12" Akron pipe arched with brick
Seven lengths 12" iron pipe
8" iron pipe
10" Akron pipe
8" Akron pipe
Bottom of channel
Bottom Channel Ref 28.5
Ledge
Earth Slope
4" Sheet piling not drawn
2" Sheet piling not drawn
Brick



No. 1
Storm Water
Sewage
No. 2
Storm Water
Sewage
No. 3
C
No. 4
No. 5
No. 6
No. 7
No. 8
No. 9
No. 10
No. 11



CROSS-SECTION OF THE SITE OF THE GARFIELD MONUMENT.—APRIL 13, 1886.

Horizontal Scale, 78 feet to 1 inch. Vertical Scale, 16 feet to 1 inch.

some injury to earth or shale. The effect of frost upon shale is to make it crumble and flake off, and in time to change its nature and return it to its original state of clay. Therefore we should remove from the site of the foundation all material that has been in the least affected by the frost or the elements, and sink our pit to a greater depth than these have penetated. In large buildings it is usual to make the depth of foundation at least one-twelfth of the height of the structure above ground. In this case, the above rule would necessitate a depth of 18 feet 9 inches below the surface of solid ground. Let us see if these conditions have been fulfilled.

It was not, of course, possible for me to dig down beside the foundations at the time I visited the site of the monument, and hence I had to depend upon such information as I could obtain by inquiry among those persons who were upon the ground. In this way I obtained the following statements:

1st. The foundation when completed will be 16 feet in the ground.

2d. Fourteen feet of this ground has yet to be hauled to the site, as it will only be used for a terrace. This would give a present depth of two feet in solid ground.

3d. The masonry rests upon the shale, and hence must have a depth of from three to five feet.

Now, if the foundations were sixteen feet deep in solid ground there could be nothing said, as no one could claim that it was not safe. But the device adopted by those having the matter in charge to make the public believe that the foundations are deep enough, when in reality they far from fulfill the necessary conditions, is a very poor one, and an *engineer* who designed a structure like the Garfield Monument with the intention of placing it on top of the ground and filling new earth around it, as a substitute for greater depth, would be considered, to say the least, very reckless. Of what use is this terrace except as a protection against future frosts? And what need is there to protect against future frosts a soil that has lain exposed for centuries to the action and disintegrating effects of former frosts? It would surely be easier to go deep enough at the start, so that we may avoid the necessity of such repairs as were made at the Washington monument. And unless the depth of foundation is greater than that indicated by the above, it cannot reach the shale. Suppose that it does not, then between masonry and shale will be a layer of clay, liable to become saturated with water, and to yield under pressure, like so much quicksand, and then the great monument will lean, slide and perhaps fall. But to give them the benefit of the doubt, let us assume that the masonry reaches and rests upon the shale.* If upon the top of the shale, it is on a crumbling, flaky substance which will easily be compressed under the weight, causing the tower to lean, the walls to crack and open, and, if no worse results follow, we shall have a structure that will *look* unstable even though it may stand. To avoid such a result, the pit for the masonry should at least pass through the strata which may have been touched

* By the statement of Mr. Frank Ford, C. E., who is in charge of the monument, there has been left a layer of *clay* 12 to 15 inches thick between the footings and the *shale* so that the "benefit of the doubt" will *not* be allowed the trustees. – J. R.

by the frost. This has *not* been done, therefore we may expect some great developments in the effects of frost upon shale.

Again, as the monument is at the crest of a hill, there is a chance of its great weight producing a lateral motion of the surface soil, and as this is ready to move now on account of the above-mentioned action of water and frost, it is evident that the chances are greater *against* the monument remaining where it has been located than in favor of it. The depth of 18 feet 9 inches would have secured its stability in that particular, and if it stood in the valley below a much less depth would have answered, perhaps as little as 10 feet.

The use of Berea stone for the outside face, in conjunction with a brick backing, seems rather strange. It is well known that this stone, where exposed to the air and to the action of frost, will crumble and spawl off. In foundations it is good on account of its strength and will last very well, as long as it remains under ground. The presence of iron in the stone is a fault, especially in regard to its appearance. It gives the stone a stained and unsightly face, which, with its tendency to crumble, will make the monument a sight which will excite the disgust, instead of the admiration, of future ages. The following table, showing the comparative resistance of various building stones to the action of frost, is taken from *Van Nostrand's Magazine*, June, 1876, from an article on the "decay of building stones." The specimens were exposed for 14 days to the effects of freezing and thawing alternately.

Name of Stone.	Relative resistance to the action of frost.
Trenton limestone, New York	1.0000
Onondaga " "	0.7878
Dayton " Ohio	0.3778
Columbian marble, Vermont	0.7079
Red granite	0.5872
Gray granite, Barre, Mass	0.4193
" " Keene, N. H.	0.3276
Fox Island granite, Maine	0.2389
Indiana sandstone	0.3517
New Jersey "	0.3139
Potsdam " New York	0.3001
Berea " Ohio	0.2526

This shows that Berea sandstone is not very good for the purpose for which it is to be used. The question will naturally arise, why did not the trustees keep to the design of a granite monument? I am inclined to believe that they wished to obtain a greater height for the same money—that is, were influenced by the relative cost. But they should have remembered that it was the *quality*, not the *quantity*, of work that ought to have been required.

As to the artistic effects, I do not feel competent to enter into a discussion. I leave them for the artists and architects of the world to criticise, and will merely state that the resemblance of the monument to a lighthouse has been always present in my mind. And will future generations admire the monument to our honored president, or will they

gaze in pity and disgust upon a moss-grown, crumbling ruin, a second leaning tower, a monument to the conceit of those *practical* men who think that all knowledge, except their own, is *theoretical*, and therefore useless ?

ABSTRACT OF DISCUSSION, APRIL 13 AND 27 AND MAY 11.

April 13.—Mr. Ritchie said that the thickness of clay covering the shale was from 3 to 5 feet.

Mr. Searles then said that these figures corresponded with his observations. The clay on the surface was originally shale, which has become disintegrated by the action of frost, heat and moisture, as the surface became eroded and the underlying shale was more and more exposed to the action of frost. He had watched this process going on for twenty years. He found that from 6 to 8 inches had crumbled or been washed away by storms in this time. Unless the monument succumbs to the action of the elements, it will be left after a time on a pinnacle by itself.

Mr. Eisenmann said that between the red clay on top and the yellow clay there was a layer of disintegrated shale. He also said that, in regard to depth of frost, he had found frost 7 feet down in shale, at the boiler room foundations of Case School.

Mr. Rosenberg said : Of late we have observed that some of our foremost buildings are deteriorating. It is not enough to produce the highest structures in order to outdo Europe ; it is also necessary to build them upon a lasting foundation and to make them secure above the foundation. I refer to the Washington Monument, to the Capitol at Hartford, the Capitol at Albany, the new city buildings of Philadelphia, to the Cook County Court House in Chicago. In regard to the latter Mr. Barbot said to me that in a panel between two windows, for a height of 5 stories, he counted 74 cracks, each of which was large enough to admit a finger. The construction of all these buildings is lacking in security. I would refer to some of the works of Sanso Vino and his contemporaries in Italy. We find that buildings that have their foundations under the bottom of the river, each in its thickness sufficient to carry 3 and 4 times the thickness of the wall above, are clamped in the bonds with lead-covered iron clamps, and the joints above ground are raked out to the depth of several inches and filled in with lead. This is doweled into the back mortar and tinned on the face. Dimensions of the stones thus bonded are often 24 feet long by 4 feet high and through stones.

April 27.—After some routine business had been transacted, the President stated that the meeting had been called to continue the discussion of the Garfield Monument, and added : This is a matter in which not only every man in Cleveland, but every citizen of the United States, should take an interest. We cannot hesitate to speak an opinion upon any point touching it. No man can be offended by the statement of a fact. Upon some points Mr. Ritchie said he was not certain ; these we must take as apochryphal. His criticisms must lead to a very close investigation. We have gentlemen with us who can fill up the doubtful points left by Mr. Ritchie, and can tell us something about the foundations which he could not see. It is a free question, and we court fair discussion.

Mr. Ritchie then said: Some of my information was obtained by actual observation, the rest by inquiry at the site and of those who had visited it. There were several contradictory statements as to the depth of foundation and the nature of the bottom. One gentleman visited the site when the pit had been excavated and the bottom leveled and the derrick set in position. He asserts positively that the bottom was clay. the depth on the highest side was 2½ feet and on the lowest side 1½ feet: Others asserted that the masonry rested on the shale. One man told me the masonry would extend 16 feet into the ground, but also stated that 14 of the 16 feet would have to be brought to the monument and piled up against it. Mr. Ritchie then drew a sketch of the site, showing the profile of ground on centre line of structure. He said the depth of clay is from 3 to 5 feet and the dip is about 10 degrees towards the southeast.

Mr. Force then requested Mr. Frank Ford, engineer in charge of the monument, to make some statements. Mr. Ford said that he had supposed he knew a good deal about the subject, but that he had received much information that was new to him; that the statements of Mr. Ritchie were nearly all erroneous; that if any questions within a certain scope were asked him, he would answer them. In reply to a question he then stated that the west part of the building was on shale and the east part on clay. Mr. Ford said in response to a resolution requesting those present to make statements of all facts bearing on the subject: With regard to the foundation, I had nothing to do with the work till after its location, when I was asked by the trustees to give my opinion. Excavations had been partially made. I advised them to put their foundations two feet deeper. I then had a man go over the ground with me with a pick and shovel. From actual examination of the clay-cutting I ascertained the solidity and the pitch, and satisfied myself that we should get as good a foundation there as anywhere, and I told Mr. Wade so. Major Overman also went over the ground, and came to the same conclusion. We were satisfied that it was capable of bearing the *weight of the structure*. The excavation for roadway is a benefit instead of being an injury, as it turns away the water and keeps the foundation dry.

Mr. Morse asked: What is the pressure upon the clay per square foot? Mr. Ford replied that that question had been settled to the satisfaction of the architect. He had nothing to do with it. The depth to which the foundation was dug was also settled by the architect, but he had suggested it be put down two feet deeper. He did not wish to criticise the plan of construction. Berea stone was selected for reasons best known to the trustees. He would have preferred granite, but the expense was too great. Berea stone had been used for a long time and was not an experiment. As far as work done under his direction was concerned, he had nothing to say. There was a statute allowing a man to refuse to answer questions that might criminate him. In reply to questions by Mr. Laman, Mr Ford stated that none of the tower foundations proper stood upon shale. The shale was under a part of the outside tower. There was less than one-third upon shale. There were two footing courses, 8 and 9 feet wide respectively.

Mr. Searles then stated that from his own observations he had made

some calculations, and he drew a sketch of the tower and adjoining vestibule. He stated that the tower is double, one within another. The main height and greater weight are with the inner tower. The inner and outer towers are connected by floors and arches. At the base is the crypt for receiving the remains. This is surmounted by an arch or dome. The tower is octagonal at the bottom and round at the top, and is supported by eight piers.

Mr. Ford then said : The weight cannot be separated between this inner and outer circle, because they are connected by arches and doorways, and by other means by which the weight is partially borne. There are 8 piers built to correspond with the octagonal shape of the inner wall. The foundations project a foot on each side of walls. The outer tower, as well as the inner, may be considered as composed of columns.

Mr. Searles : I would like to ask Mr. Ford if the outer wall foundation course is a continuous course of stone.

Mr. Ford : There are two continuous footing courses under the outer wall and one stone makes the width. The annular space between the inner and outer towers forms a walk all around nearly at the level of the foundations. About the level of the water table there is an arch, and there are other arches at intervals.

Mr. Force : Are the footing courses of the inner and outer walls independent?

Mr. Ford : They are independent.

Mr. Force, after making a few calculations, said : If the inner walls have about the same load as the outer, the pressure per square foot on the clay would be nine and three-tenths tons.

Mr. Searles : It would be a very simple matter to calculate it, if the walls were solid, but they are full of openings. Then we have the different floors and these may have different weights. At the foundation, we have the outer wall footings, a circular ring nine feet wide on the clay, and inside the eight piers containing fifty square feet each on the clay. The diameter of the inner octagon is thirty-six feet ; of outer, sixty feet. The cutting for the roadway shows the character of clay and shale. There is no clear line of demarcation between them. While the clay is thoroughly apparent and the shale thorougly stratified, there is an intermediate stratum, showing that the process of decay which I alluded to at our last meeting, is still going on, and that the clay was originally shale. I found red clay on top entirely different from the lower strata. The shale is what is called black shale.

Mr. Morse : We must know exactly what the pressure per square foot is on the clay.

Mr. Ritchie : Mr. Force has figured that it was a little over nine tons. The Washington Monument was considered unsafe with a pressure of five and six-tenths tons per square foot, but the clay under the Garfield Monument is much stronger than the soil under the Washington.

Mr. Force : The pressure now is about three and one-half tons per square foot for the Washington Monument, as discussed at the convention of the civil engineers. The repairs and improvements have decreased the pressure per square foot.

Mr. Searles asked Mr. Ford what depth of clay remained between the lower footing course and the shale.

Mr. Ford: In digging down for the foundations, one corner struck shale. I have forgotten the depth.

Mr. Force: I am free to say that the clay is overloaded. It must be better than any clay I ever saw if it stands 9½ tons. I should not expect to see it stand more than four and one-half tons.

Mr. Mordecai: What is the load on the viaduct draw foundation?

Mr. Morse: About 5½ tons per foot.

Mr. Force: On ordinary sand 1½ tons per foot is load enough, and too much for some gravels. On the central viaduct now started we are loading half a ton to the foot on smaller piers, and load on foundations will not exceed one ton per foot. In the case under discussion 4½ tons is load enough.

Mr. Searles: At the Plattsmouth bridge the span is over 400 feet. The piers are on clay just below the river bottom, which is shifting sand.

Mr. John Walker: The foundations have been shown to be independent in the two towers. This alone should condemn it. I should put the base on one solid foundation. In this case there may be uneven settlement.

Mr. Force: The abutment at the south end of the Kingsbury Run viaduct has a load of 1½ tons per foot, and has settled about one-quarter of an inch. I would not load its base with more than two tons to the foot. It is not as stiff clay as what the monument stands on, however.

Mr. Ritchie then called attention to the tower of the Cleveland Water Company at East Cleveland, and requested some figures as to its foundation.

Supt. Whitelaw and Architect Bate gave the height as 236 feet; depth of foundation, 11 feet, of which 7 feet was excavated out of shale. Weight on foundation per square foot is about three tons. No settlement shown as yet.

Mr. Holloway: The amount of weight a structure will carry depends upon how it is balanced. The foundations of any structure are influenced by the surroundings. If they are laid so as to prevent any displacement, they may be secure. If the material cannot get away in any direction, it can be compressed very much. A hard, compact material may carry a heavy load. Mr. Ford says there is an additional wall to hold that clay in.

Mr. Ford: The shale in that hill is 60 or 70 feet thick. It is equivalent to solid granite.

Mr. Whitelaw: The criticisms have been that part of the structure rests on clay of unequal thickness.

Mr. Ford: The slope of the shale is about one in seventy.

Mr. Whitelaw: That would make the thickness about six inches more on one side than on the other.

Mr. Ford: The tower foundation is all on the clay.

Mr. Whitelaw: It is a good practice to rest the whole structure on the same material if possible.

Mr. Latimer then requested Mr. Ritchie to show the table of the relative resistance of stones to frost given by him at the preceding meeting.

Mr. Ritchie then recapitulated briefly his statements with reference to the relative resistance of various stones to frost. In reply to Mr. Lati-

mer's question, why he did not give all the stones mentioned in Brand's frost test, he said that he had given several specimens of each. He had taken Trenton limestone as the standard. He considered Fox Island granite the worst of the granites. He had given four specimens of sandstone. He had nothing to say against Berea sandstone as sandstone. In its proper place it was very good stone; but, in the Garfield monument, or any monument intended to last a long time, it was out of place. We could see by inspecting the Cleveland viaduct that it was wearing away. The use of Berea sandstone in the monument was a mistake, because it had not been used long enough for people to be certain whether it would stand the test of the climate. He did not think the evidence went to show that it would stand.

Mr. Latimer then read a paper handed in by Mr. Cooper, of Berea, with reference to the enduring qualities of various stones. Mr. Cooper said he had taken it from Seward's "Trip Around the World."

Mr. Latimer: Sandstone is considered by engineers and architects to be one of the best building stones. Nelson's monument was built of it. With few exceptions, the temples of Thebes are built of sandstone. St. Paul's Cathedral, in London, built by Sir Christopher Wren, was of oolitic limestone. The stone was quarried and exposed on the sea beach for three years before it was used. It is the only stone not affected by smoke in London.

Mr. Whitelaw: Any one who looks at the tombstones in the Erie street cemetery will find that the inscriptions on many of them are entirely obliterated.

Mr. John Walker: You can read epitaphs on gravestones hundreds of years old in England. The difference of climate has all to do with it.

A member stated that one of the sandstone towers of the cathedral at Cologne crumbled and had to be replaced.

Mr. Barber: Some of the top layers in the quarries at Berea are unfit for buildings exposed to the weather. I understand that within the last few years a layer or stratum of different quality has been reached, known as the 10-foot stratum. I am told that this is to be used in the monument. It is superior, both from the absence of sulphur and the absence of iron. I think the enduring qualities depend more upon the lithological than the geological character.

Mr. Latimer: Magnesian limestone does not last in London, but does well as building stone in the country.

Mr. Force: Red sandstone in New Jersey is affected by absorbing another part of oxygen; one layer is such that it does not take any more oxygen, another layer absorbs an additional part. The stone for some of the bridges has been taken from the best parts of the quarry.

Mr. Morse: I have been through the Berea quarries, and I have seen some good building stone got from this 10-foot sheet. In taking a large amount, there would be occasional poor stone. On the Columbus road there is an arched viaduct. About twenty years ago I noticed that the stones on the north side were discolored—stained with iron which had come out of the stone. The viaduct had been up twelve years. That iron is now washed away, and the stone appears more of a uniform color, and apparently has not disintegrated. I think the iron will work itself out after a time.

Mr. Searles exhibited a diagram representing the sandstone and brick of which the monument is composed—a stone facing with brick backing. The wall is about seven feet thick and less as you go up. The stone is from eight to twelve inches deep, a veneer as if to protect the brick from the weather. To prevent the separation of the brick and stone there are iron clamps of a Z shape. Whatever stability there is in the wall is due to the brick. The weight is sustained by it. The brick is of an ordinary good quality. The stone appears to be ornamental. The cement used is Louisville cement.

Mr. Morse: The brickwork will settle more than the stone in ordinary buildings.

Mr. Force: The Washington Monument is veneered with marble; marble on the outside and stone on the inside.

Mr. Searles: The lower courses were supplied with one stone from each State.

Mr. Mordecai: The upper courses are solid stone.

Mr. Latimer: There was a stone sent from each nation of the world.

May 11.—After some routine business Mr. Latimer said: Mr. Kellar, the architect of the monument, was here the other day, and I had some conversation with him upon this subject. He said he would be glad to write me a letter with regard to it. I received the letter to-day and will now read it to the club.

LETTER FROM THE ARCHITECT.

Mr. Charles Latimer, President of the Society of Engineers, Cleveland, O.:

DEAR SIR: According to your request, I send you the following facts and figures relating to the foundation of the Garfield Monument for the information of your Society. The original drawing contemplated that the footings should go down to the shale. While I was in Cleveland procuring proposals for the work, Mr. Linas, a well-known builder of Cleveland and one of those invited to bid on the work, told me that he had been to the site and inspected the ground, and found that it would be necessary to go down eighteen inches lower than my drawings indicated in order to build on the shale. I accordingly altered the specification so as to read: "Excavate for the foundation of monument two feet lower than is shown on drawing No. 2." Last November I was called to Cleveland in regard to the foundations, as there had been some criticism on them, and on my return to Hartford made the following memorandum:

HARTFORD, Nov. 20, 1885.

Before making the working drawings for the Garfield monument, I went out and surveyed the site, and examined it carefully in order to decide the probable depth necessary for the foundation. I observed from the road cuttings on each side that the site was of a soapstone shale character throughout, which seemed to reach almost to the surface of the ground. I also noticed that this shale or rock was perfectly level to all appearances in its stratification, and that the ground was high and well drained on all sides. I also conversed with Mr. Linas, an experienced builder, who expressed it as his opinion that every foot we put the foundation below the top of the shale was so much money wasted. When procuring estimates for the work, I visited the quarries at Berea, Ohio, and observed several good-sized houses standing directly over similar foundations of soapstone rock and shale. I still further discussed the depth of the footings of the monument with the prominent builders in Cleveland, who all assured me from their experience and knowledge of the site that I had provided abundant foundation for the monument. After the contract was awarded, I wrote to Mr. Simmons, the mason

having the contract for the work, that if there was any doubt in the minds of the committee or himself as to the foundation, that I would start immediately for Cleveland to still further consider the matter. Mr. Simmons, in his reply, said that they had gone down some three feet deeper than the drawings showed, and had reached a very hard clay which he considered suitable, and that Mr. Wade had had experienced engineers to examine the site before any stones were laid and they united in the same opinion. After the foundation walls were up about six feet all around, I went to Cleveland and saw the excavation for foundation bed where stone was not laid, and am decidedly of the opinion that the monument will suffer no damage from its foundations not being deep or broad enough. The ground is high and well drained. The footings are a continuous ring and not isolated piers, so that the weight is distributed uniformly. Calculating the Berea stone at 134 pounds per cubic foot and the brickwork of backing at 112 pounds, there is about 9,000 pounds to each superficial foot in footings under outer wall. Major Overman, United States Engineers, and Mr. F. Ford, civil engineer, before the work had fairly begun visited the site at the request of Mr. Wade, the chairman, and inspected the foundation bed. Both of these experts pronounced it in every way sufficient to receive the walls of the tower. This conclusion they arrived at separately, independently, without knowledge of each other's opinion. Mr. Simmons, and all whom I have consulted, men of experience, agree that the foundation is ample and suitable.

The above memorandum was written last November, and nothing has occurred since to change my opinion. The inner wall of the tower, which is concentric with the outer wall, is pierced with numerous openings, and the footings under it have less weight to sustain per superficial foot than the outer wall. In the paper read before your Society there were several misstatements.

First. One end of the tower does not rest on shale and the other rest on clay.

Second. The shale does not pitch to the east at an angle of ten degrees, but is very nearly level, pitching not more than one degree to the east, if at all.

Third. The slope of the ground covered by the monument from the east to west is but one foot instead of six or seven.

Fourth. It is absurd to say that the water runs up the surface of the shale and trickles down at the west of the monument, for the shale pitches from west to east.

George Keller.

Mr. Ritchie: In that letter does Mr. Keller mention the dip of the strata or the slope of the surface?

Mr. Latimer: He says the shale does not pitch to the east at an angle of 10 degrees, but it is very nearly level, pitching not more than one degree, if at all. The slope of the ground covered by the monument from east to west is but one foot instead of six or seven.

Mr. Ritchie: The monument stands on the crest of a hill. I said in my paper that the surface of the ground falls off to the northwest, with a grade about one foot in twelve, and although the monument stands on the crest of a hill, it is but a short distance from the edge. The dip of the strata is toward the southeast, and I am certain it is not less than 10 degrees.

Mr. Rice: It is probable that if the club discuss this on the facts presented by the architect, those facts might be contradicted. It might be well to get an official statement. Mr. Rice then presented the following resolution:

Whereas, The discussion of the Garfield Monument has, to our regret, been construed as influenced by personal motives, and in justice to the grave public interests, trusts and professional opinions involved,

Resolved, That this Club, through its President, appoint an expert committee of five members, who shall request the trustees of the Garfield Monument to afford access to all plans, specifications, details, and every other information for their use, and to give the committee every facility for making a thorough examination of all the engineering questions involved; said committee to report to the Club its findings at the earliest possible date.

Mr. Searles: There has been a good deal of discussion to the square foot, considering the size of the monument. It was remarked some time ago that it would be well to get at the real facts from those in authority. The engineer of the monument was present at the last meeting by invitation, and made various statements. Since that the architect has been in the city and has made statements. I have figured out for myself about the real condition of the case. This document just read again throws some haze upon the subject, as it contradicts former information from the writer and also information from the engineer. Therefore I am inclined to favor this motion. In my investigation I have taken pains to throw out the information given by Mr. Ritchie, and have adopted only that obtained direct from Mr. Ford or Mr. Keller. A brief résumé will be in place here.

Since the charge has been made in the public press that some who have been misled by known falsehoods call the foundation of the Garfield monument unsafe, and since this charge is a reflection on the members of this club, who have been earnestly discussing the structure, it may be well to investigate this structure in the light of the *known facts* as furnished us by the engineer and the architect of the monument. From these sources we are informed that the pit dug in the clay under the masonry and above the shale is about twelve inches on one side of the tower and about 15 inches on the other, the difference being due to the dip of the shale. The monument consists of an outer tower inclosing an inner shaft. These are connected at different levels by floors supported on brick arches. The tower is of brick, faced with Berea sandstone; the latter from 8 inches to 12 inches thick. The height of the monument is 238 feet to the top of the finial. The shaft is about 20 feet higher than the tower walls, projecting above the roof that covers the latter. The tower rests on a circular footing course of 9 feet wide. The shaft rests on eight distinct pedestals 7 by 7 each, and these are not connected in any way with the tower footing.

The clay on which the masonry rests is common yellow clay of this vicinity which overlies the shale. In a state of nature, water exudes from the shale, but this is believed to be cut off from the foundation by an excavation made for a roadway entirely around the structure. Now, taking the above data just as furnished us, it is easy to approximate the weight of the structure and the weight per square foot on the clay. We thus find that the tower pressure is 6 tons per square foot on the clay, while the pressure of the shaft is no less than eleven and three-eighths tons per square foot on the clay. Let us see how this agrees with the weight given by the engineer. The total weight as found above is 9,579.6 tons for the tower, and 4,547.4 tons for the shaft, making a total of 14 127 tons, or an average of 7.07 tons per square foot of the entire foundation.

Now the engineer says that the alleged estimate of nine and a half tons per square foot was "over two tons too much," which confirms this estimate of 7.07 tons. But the real distribution of weight is even more unfortunate than shown above, for we have assumed that the floor weights are evenly divided between the shaft and tower, whereas, by the form of construction, the shaft must carry 89 per cent. of the entire floor weight and the entire tower wall only 11 per cent. Making this correction, we find the pressure under the shaft to be over 12 tons per square foot, which is four times the safe limit on such material. Prof. Rankine places the limit at 1.75 tons. Geo. S. Morison, at the Bismarck Bridge, where the clay was stratified and exceptionally hard and impervious to water, allowed a pressure under one pier of 2.84 tons per square foot and under another of 3.92 tons per square foot. That clay was so compact that a pick could not be struck into it more than an inch deep. The clay under the monument is not stratified, but plastic; the architect characterizes it as "*tough*." The probable result will be that the tower will settle so as to develop cracks where it joins the building connected with it, while the shaft loaded to twice the weight per square foot will settle twice as much as the tower, which will produce cracks in all the floors and arches between the two. These cracks will probably show the first year after construction, and go on increasing an indefinite period.

Mr. Mordecai: It seems to me that any investigation of the safety of that monument should come from the trustees. What necessity have we, as a society, to investigate it?

Mr. Walker: You all remember that the engineer told us that the inner tower was supported on independent piers. I think that calls for investigation.

Mr. Mordecai: I think that entirely rests with the trustees. I cannot see how this club has any right to investigate. I should consider it, if I were in charge, a very great impertinence.

Mr. Searles: Mr. Wade having referred to the discharged parties is a reflection upon the members of the club, implying that we have been discussing known falsehoods. We therefore request the privilege of discussing hard facts.

Mr. Rice: We take simply this position. They say we have not discussed on official facts. We say, then, afford us official facts.

Mr. Mordecai: It would be better to write to Mr. Wade and ask him to give us the facts. A vote was then taken upon the resolution presented by Mr. Rice, and it was declared carried. Mr. Mordecai then asked for division. The matter was decided by a rising vote in favor of the resolution, 19 members rising, 5 opposing.

REPORT OF THE COMMITTEE APPOINTED TO OBTAIN INFORMATION IN RELATION TO ERECTION OF THE GARFIELD MONUMENT, IN LAKE VIEW CEMETERY, CLEVELAND, OHIO.

[Presented June 8, 1886.]

To the Engineers' Club of Cleveland:—Your committee, in pursuance of instructions, waited upon Mr. J. H. Wade, President of the Board of

Trustees of the Garfield Monument, and requested his permission to visit the structure and examine the drawings after which it is being constructed. Permission was cheerfully granted, but the committee was invited to defer its visit until the architect, Mr. George Keller, of Hartford, Conn., could be present.

Mr. Keller having arrived on May 27th, the committee met him by appointment at the monument on the following day, and proceeded to examine the building, as far as constructed, and especially the foundations. The basement walls were at that time completed, and work was progressing on the first story of the entire building.

The length of the building, including tower and vestibule, is 69 feet, its width is 50 feet. The tower is 50 feet in diameter, octagonal at the base, and circular above. Within the tower and concentric with it is a shaft 28 feet in diameter, the basement of which is octagonal and forms the crypt. A doorway, or opening, four feet wide at each side of the crypt reduces its walls to eight piers, one at each angle of the octagon. The footings under the piers are separate from each other and from the footings of the tower wall. They consist of two courses of stone having an aggregate thickness of 30 inches. They are irregular in shape and area. The lower course is said to have an area of 60 square feet per pier. The footing of the tower wall is reported to be a continuous course of stone 9 feet wide, having an area of 1,296 feet on the ground.

Measurements and levels were taken by the committee to locate the footings with reference to the original surface of the ground. From these it appears that the depth of the foundation pit averaged only 3 feet, being 3 feet 6 inches on the upper side and 2 feet 6 inches on the lower side, owing to the slope of the surface. As the courses of footing stones have a thickness of 2 feet 6 inches, their top, which corresponds with the neat lines of the masonry and very nearly with the finished floor of the crypt when laid, is about on a level with the original ground surface at the lower side. This agreed with the architect's drawings.

So shallow a foundation would not be secure from frost, but it is a part of the plan to surround the basement eventually with a terrace of earth about thirteen feet high.

The foundation pit has been refilled with loose clay to the top of the footing courses, and this is somewhat water-soaked from exposure to the weather. The native clay below this seems to be still firm and hard, as nearly as could be judged by sounding with an ordinary steel bar. It is the common testimony of those who saw the first stone laid, that there is a layer of hard clay from 12 to 15 inches thick remaining between the first course of stone and the shale.

A vertical section of the formation is clearly exposed by an excavation about 12 feet deep made for a roadway on the north side of the monument, and about 100 feet distant. The surface clay is about 5 feet thick and rests on a bed about 2 feet thick of weathered shale, so much disintegrated as to be reduced nearly to the consistency of clay. Beneath this is the shale proper, but streaked with three seams of sand which carry a little water in the wet season, but are now comparatively dry The shale has a slight dip to the southeast.

After completing its investigations at the monument, your committee

adjourned to the Stillman House, where Mr. Keller exhibited the plans, elevations and sections of the structure, also a copy of the specifications. These were carefully studied for several hours, with a view to obtain as nearly as possible the actual weight of the tower. Mr. Keller kindly explained his drawings in detail and very materially aided the committee in their labors.

The walls were first estimated as solid and then the actual openings were deducted, leaving the net cubic feet of material.

The arches and domes were separately computed, with their spandril filling, also the floors and roofs. The following units of weight were assumed:

Berea sand stone, per cubic foot	134 lbs.
Brickwork in cement, per cubic foot	112 "
Cinder in spandrils " " "	65 "

The tower walls are 180 feet high above the footings. They are seven feet thick in the basement, 4 feet 6 inches thick above the water table, and less higher up. They contain:

40,114 cubic feet of Berea stone (134)	5,375,976 lbs.
38,755 cubic feet of brickwork (112)	4,340,560 "
One-half of the galleries weighs	305,000 "
Total weight	10,021,536 lbs.
Area of foundation, 1,296 square feet.	
Weight per sq. ft., 7,732 lbs., or	3.866 tons.
Pressure on one side of base, due to 50 lbs. wind pressure on vertical section, 3,000 lbs., or	1.5 "
Maximum load on tower per sq. ft.	5.366 tons.

The inner shaft is 200 feet high from the footing to the base of the spire. The finial is 238 feet above the footing. The basement piers and walls are of Berea stone 4 feet thick. The upper walls of the shaft are of brick, supported by eight granite columns on the main floor. The walls are three feet thick and less. The following are the estimated weights:

Basement piers	866,176 lbs.
Columns and walls above	2,616,656 "
Domes and floors	401,760 "
Galleries and staircases	356,080 "
Upper dome	46,917 "
Upper staircase	117,555 "
Spire	161,604 "
Total	4,562,748 "

Area of footings, $60 \times 8 = 480$ sq. ft.

Dead weight per sq. ft., 9,506 lbs. = 4.753 tons.

There are five floors, the aggregate area of which is 6,280 square feet. When these are filled with people at 80 pounds per square foot, the total live load will be 502,400 pounds. The shaft carries 79 per cent. of this, or 396,896 pounds. One pier carries 49,612 pounds.

Live load per square foot of foundation 827 lbs. =	0.413 tons.
Dead weight as above of shaft	4.753 "
Total weight per square foot (maximum)	5.166 "

The weight of the vestibule was not calculated, but as the building is only one story high above the main floor, the load per square foot of the foundation will probably not exceed one ton.

It will be observed that the weight of the tower here given is considerably less than the weight estimated in the late discussions of this subject. The error was due to the imperfect data at that time available. But the load is still great enough to cause some compression in dry clay. Were the settlement uniform over the entire foundation, no harm could ensue, but the inequality of pressure in the several parts leaves a doubt in the mind of the committee as to the probability of uniform settlement. The dead load of the shaft being 4.75 tons against 3.86 in the tower suggests a possible greater settlement of the shaft, to the detriment of the gallery floors and arches; while the weight of the tower, 3.86 tons per sq. ft., against, say, one ton for the vestibule, warrants the apprehension that any settlement will cause these walls to crack, since they were all carried up at the same time and were thoroughly bonded together.

The contingency of any settlement whatever might have been obviated by carrying the pit down only a few feet further to the solid shale, and then filling the space with concrete, well rammed, before laying any stone. This treatment would not only have transferred the pressure directly to firm foundation, but would have also combined and distributed them in such a manner as to render them nearly uniform over the entire area.

J. H. Sargent,
J. M. Blackburn,
C. H. Strong,
Wm. H. Searles. } *Committee.*

DISCUSSION FOLLOWING THE READING OF THE REPORT OF THE COMMITTEE.

Mr. Searles: It is possible that the club would like to discuss this report. I would like to say in addition that the data given before we obtained this information was imperfect. These figures are correct.

Mr. Richardson: Did the figures of the architect agree?

Mr. Searles: These are the figures of the architect. He had taken pains the evening before we met to go over the figures with the assistance of the engineer, so that when the committee got to work it was easy to go over the ground. He said that the figures first given were very rough. He had only assumed what they would be, but he adopts now the figures we have presented this evening.

Mr. Ritchie: Did the architect make any design for the foundation or did he simply make the design for the monument?

Mr. Searles: We obtained from the architect this explanation: Not being present to see the site of the monument, he understood that it was on solid rock. He drew his design with the view that the floor should correspond with the surface of the rock. When he understood that there was a little clay, he instructed them to go down to the shale. He afterward ordered an additional depth to be put into the pit, but after all the shale was not reached. The stratum of hard clay was considered sufficient by those in charge. The architect was not present. The misappre-

hension arose from the supposition that there was hard rock to build upon.

Mr. Swasey : The architect has done everything in his power to aid the committee, and I propose a vote of thanks.

On motion, a vote of thanks was tendered to the architect, trustees, engineer, and all who had aided the committee.

SOME OF THE ENGINEERING FEATURES OF ILLINOIS DRAINAGE.

By I. O. Baker, Member of the Western Society of Engineers.

[Read September 7, 1886.]

Having during the past summer given considerable attention in one way and another to drainage matters, the writer thought that possibly he might be able to gather up a few items which would be of interest to the members of this Society. It would be difficult for one who has not investigated the matter or who has not mingled freely with the agricultural community to appreciate the magnitude of the drainage craze which has taken possession of the people of this State. For a number of years, large sums have been spent in tile drainage, in the year 1883, the last year for which the record is made up, nearly 12,000 miles were laid ; but very recently the drainage problem has taken a new phase. Within a few years past attention has been directed to the drainage of numerous comparatively large flat tracts of land which it had been considered impossible to drain. This article refers only to the latter.

A recent article in *Science* states that there are 50,000 square miles of swamp land in the United States east of the Mississippi ; but, if the term swamp land is interpreted as it is in Illinois, there must be many times that amount. By act of Congress, the General Government gave to the States all the "swamp and overflowed lands" within their borders ; under this act, Illinois claims nearly 3,500 square miles. Although there is nothing like that amount of undrained swamps or overflowed land now in the State, yet the amount of undrained land which will require construction of large ditches for outlets is considerably larger. Judging from one or two counties with which the writer is pretty well acquainted, it may possibly be twice as great. The drainage enterprises of Illinois properly are not the drainage of swamps but the cutting of large canals to serve as outlets for tile drainage. The area to be drained frequently includes swampy tracts, but by far the larger portion is already partially drained. In the estimate in the article in *Science*, Illinois was probably credited with comparatively a small amount of swamp land.

According to that article half of the estimated swamp lands of the United States consists of tide-water marshes along the South Atlantic and Gulf coasts, and doubtless only a small part of this was assigned to Florida : yet there is a single drainage scheme now in progress in the southern half of that State which will redeem for agricultural purposes 17,000 square miles. This is given to show that there is a large amount of land in the United States, in addition to the swamps, which is now too wet for agricultural purposes, and which can be greatly improved by

proper drainage. For reasons not difficult to discover, a large part of this area will soon be won to a much more successful agriculture. When the work of redemption is commenced the services of the engineer will be called into requisition. A word to the wise!

There is one respect in which the drainage enterprises of Illinois differ from any other of which the writer knows. In this State the land to be drained is owned in comparatively small tracts, and any drainage scheme of the kind under discussion will affect a number of proprietors, and consequently the work must be carried on by the combined efforts of a community. In England, in Holland, and in Russia, each of which is noted for the magnitude of its drainage enterprises, the land was owned by the government, and the work of its redemption was carried on at the expense and under the direction of the government. In Florida and Louisiana some large drainage schemes are in progress, but in each case the land to be drained is owned by a single large corporation, which bought the land of the State for a mere song. The drainage districts of Illinois are the only instances in which the co-operation of a community has accomplished results equal to those attained by governments or by wealthy corporations. Although the drainage enterprises of Illinois are neither the most expensive nor the most extensive in the world, they surpass any in the ratio of cost to results.

The work is under the direction of three commissioners, elected annually by the interested land owners. The money is raised by special taxation according to the benefit as assessed by a jury appointed by the court for the purpose. The commissioners are empowered to borrow money and issue bonds. It seems to be generally conceded that the Illinois drainage law is better than that of any other State. The Illinois law seems to be superior in that it gives the three commissioners sole charge, with unlimited authority. Under commissioners with unrestricted powers the work proceeds as a unit, economically and rapidly.

The commissioners "have power to employ a competent civil engineer, if in their opinion the services of an engineer be necessary, who shall thereupon proceed to make such survey and estimates as the said commissioners may direct, and shall make and return to the said commissioners a map or plat of his survey, and a full report of all estimates so required of him." He "shall receive not to exceed $5 per day for the time actually employed." It will be noticed that the engineer is entirely subordinate to the commissioners. The engineer surveys the line of the ditch, takes the levels, draws the profile and plats, and computes the amount of earthwork. Since the ground to be drained is generally a broad flat tract, the ditches are usually quite straight, so that the location presents but few difficulties. Often the ditch follows the division lines of the land. There is much debate among land owners as to the best form of cross section. As a rule farmers prefer a shallow ditch, on the ground that it will be injured less by stock than one with high banks. This may be all right for small ditches, but unfortunately the same ideas have sometimes prevailed in designing the large outlet canals. However, the introduction of steam machinery has incidentally remedied this partially. No care seems to have been taken to adjust the capacity of the ditch to the probable amount of water to be carried.

The largest ditch in the State is $17\frac{1}{2}$ miles long, 30 feet wide on top at the upper end, and gradually increasing to 60 feet at the lower end, and from 8 to 11 feet deep. There are a number of ditches 30 to 40 feet wide, 6 to 8 feet deep and 10 to 15 miles long. The minimum fall is about 1 foot per mile; and generally the fall is two or three times as much.

The smaller lateral ditches are generally constructed with drag scrapers, although occasionally a road grader is used to construct a flat V ditch which is deepened by running a capstan plow in the bottom of it. Sometimes the capstan plow is used to deepen a scraper ditch. In fact, the capstan plow is employed whenever it is possible, and is a very valuable machine for making small ditches or deepening larger ones. It is said to be peculiar to Illinois. It consists of two triangular mold boards, joined in front and standing at an angle of about 90° with each other; the plow is propelled by two cables attached to capstans driven by oxen or horses. The ordinary capstan ditch is 1 foot on the bottom, 4 to 6 on top, and $2\frac{1}{2}$ to $3\frac{1}{2}$ feet deep. Three men and two teams make 100 rods of such ditch in a day easily. Wings are sometimes attached to the plow, which roll the earth back from the edge of the ditch, leaving a very pretty ditch. One man has attempted to utilize the pressure of the water behind the plow, and thereby be able to construct a much larger ditch. So far it has not been a complete success; when there is a large quantity of earth on the mold board, it shoves along in front of the plow instead of sliding along the mold board and up and out of the ditch.

The larger ditches are generally constructed with steam dredges. The most common form is the boom dredge, *i. e.*, a steam shovel mounted upon a scow. The largest boats are 80 feet long, 36 feet wide, boom 60 feet long, $1\frac{3}{4}$-yard bucket, 32 horse-power engine, and cuts a ditch 50 feet on the bottom and leaves a berme of 10 to 12 feet. Such a machine will cut about 1,200 yards in 10 hours. The smallest dredge cuts a ditch 16 feet wide and from 4 to 6 feet deep. The chief advantage of a steam shovel mounted upon a scow is that it is not stopped by the water; but on the other hand, in a dry season like this, it is sometimes stopped by the lack of water. The chief defect in the steam dredges as operated at present is the great amount of time consumed in raising and lowering the anchoring spuds, and in moving ahead; in a small ditch nearly one-quarter of the time is thus wasted. It does not seem that it would be difficult to remedy this defect.

One contractor is operating a shovel upon a frame or "mud boat" which rests upon the bottom of the finished ditch; it is moved forward by a cable anchored ahead, one end of which is wound up by the engine on the drag. This device seems to entirely remove the above defect.

There is one dredge of the endless chain and bucket type at work in the State. It is similar to the ones at work in Florida and Louisiana. The design seems to be very faulty in several particulars, but it looks as though a machine could be built on this principle which would excel the boom dredges. We have not yet arrived at anything like perfection in the way of machinery for excavating ditches. The capstan ditcher, and both forms of dredges, are susceptible of great improvements. As the results of the present drainage enterprises become better known, and as

the increase in population demands the redemption of all swamp lands, and the better development of those already occupied, drainage matters will of necessity receive increased attention, and the services demanded of the engineer will be of a higher order than at present, and the machinery employed will be more efficient than that now in use.

The price for capstan-ditcher work is the equivalent of 4 or 5 cents per cubic yard: it is usually done by the rod. Scraper work is ordinarily from 8 to 12 cents, with an occasional job as much as 16 cents. Dredge work ranges from 11 to 17 cents.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 15, 1886:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M., President George L. Vose in the chair: nineteen Members and six visitors present.

The record of the last meeting was read and approved.

Messrs. G. A. Bobrick and E. Harrington were elected Members of this Society.

Mr. Theodore P. Perkins was proposed for membership, recommended by G. A. Kimball, A. L. Kidd.

On motion of Mr. Henry Manley, it was voted: That the Society pay four dollars of the membership fee due from Mr. Harrington, because of his earlier membership in the Society.

The President announced the death of Professor William Ripley Nichols and E. S. Chesbrough, Members of this Society.

Professor G. F. Swain was requested to prepare a suitable memorial on the death of Professor W. R. Nichols.

On motion, it was voted: That the Government be requested to appoint a committee to prepare a suitable memorial on the death of E. S. Chesbrough.

Professor G. L. Vose read a sketch of the life and works of Major George W. Whistler.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

JUNE 16, 1886:—A regular meeting of the Engineers' Club was held at Mercantile Library, President McMath in the chair.

The resignation of T. D. Miller as Secretary was read and Wm. H. Bryan was elected to fill the vacancy for the unexpired term.

M. L. Holman read an informal paper on "Fire Streams," calling attention to serious discrepancies in figures given by the highest accepted authorities on the subject. It was shown that the formulæ of Weston and Ellis varied largely in results, both as to quantity of water and pressure necessary to throw fire streams of given dimensions. The Club thought it advisable to secure further experiments on the subject, and a committee, consisting of Robert Moore, Prof. Woodward, M. L. Holman, W. T. Angell, and Wm. H. Bryan, was appointed to investigate the matter further.

The Club then adjourned to meet again on the third Wednesday in October.

WM. H. BRYAN, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

June 7, 1886:—The regular monthly meeting of this society was called to order at 8:30 P. M. In the absence of the President and Vice-President, Mr. L. W. Rundlett was chosen chairman for the evening.

Upon ballot, Mr. J. A. Case was elected to membership. Applications from Messrs. M. Tolz and W. W. Curtis for membership were received, and notice of ballot at next regular meeting given.

The literary exercises of the evening were opened by Mr. F. T. Hampton with an interesting paper on "Cheap Motive Power," with reference to the development of such power for the manufacturers of St. Paul. The paper discussed the present efficiency of the steam engine with the causes which will limit in a measure the further development of its effectiveness.

Mr. R. E. Hilgard presented drawings of the proposed steel arch bridge, designed by him for the City of Minneapolis to replace the present suspension bridge over the Mississippi River.

Mr. Hilgard then read a paper on the subject of "Graphical Statics," showing how the science was deduced from the properties of the parallelogram of forces, and the force polygon. Notes of the application of graphics to practical calculations followed, both with reference to iron structures and to stone and brick structures. The use of the method as applied to arches was shown by the sheets of the calculation of the Westminster street tunnel arches of the St. Paul & Northern Pacific Railway at St. Paul, now nearly completed. The subject of lines of maximum compression and tension was briefly mentioned with regard to beams and struts, and then it was shown by a longitudinal section of the femur bone of a man that the material of the bone and its shape both in the external shape and the internal arrangement of the material is in accordance with these theoretical lines of maximum tension and compression.

After a discussion of the paper the meeting was adjourned till September.

Geo. L. Wilson, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE APPLICATION OF ELECTRICITY TO RAILROAD SIGNALING.

By George W. Blodgett, Member of the Boston Society of Civil Engineers.

[Read April 17, 1886.]

The part of the evening's exercises which falls to me is a brief description of the electric apparatus for railroad signaling in use on the B. & A. R.R., followed by some general considerations on the use of electricity for this purpose. I begin with

Line Block Signals with Rail Circuits.—The road is divided into sections of from one-fourth to one mile in length, according to the amount of traffic or local circumstances, each of which sections has a signal at the beginning, operated by clockwork and a weight, and which is set to danger whenever a train enters the section from any point, and restored to the position indicating safety when the train leaves the section. Each section is electrically insulated from those before and behind it. At the end farthest from the signal is an electric battery giving a constant current, which is connected to the track, one pole to each rail; at the signal end of the section the coils of a relay are connected to the rails in like manner, so that there is a constant flow of electricity from the battery through one line of rails to the relay, through its coils to the other line of rails, thence by these rails back to the battery. This relay controls the local circuit (so-called) of another battery through an electro-magnet in the signal, which governs the motion of the clockwork operating it. The successful operation of signals by a rail circuit requires that the *electromotive force* (or pressure, as it may be considered) of the battery connected to the rails shall be so small that there will be very slight leakage from the rails even in wet weather. It is found advisable, therefore, to include in a track circuit only the coils of a relay of low resistance, and make this relay open and close the circuit for another battery of any size we wish, which shall operate the signal itself. Both circuits are normally closed, that is, there is a constant flow of electricity through the whole length of each. The clockwork is so constructed that when the current is passing through the magnet, the signal is held in the position of "all clear," or "safety."

When this is interrupted, the signal takes the "danger" position. When a train enters the section the current in the rails takes the path of least resistance, through the wheels of the train, instead of the relay magnet. The armature of this relay falls away from the magnet and opens the circuit of the battery controlling the signal, and this takes the position denoting danger as long as the section is occupied. When the last pair of wheels passes out of the section the circuits are again closed, and the signal shows clear. The same effect is produced whenever, for *any* cause, either circuit is interrupted—for instance, if the battery fails, or the wires are broken, or the clockwork is run down, the signal shows "danger" until the difficulty is removed. If a rail in the track is broken, and the parts separated by even so much as the $\frac{1}{100}$ of an inch, the signal will be at danger. I have known many instances of this, and not a few when the indication was most timely. One which happened on the road with which I am connected was a break where the parts were displaced by a space of an inch or two in such a way as to be almost certain to derail a train. The next train to pass would have been a "New York express"—a heavy train, running at a high rate of speed. The track was on an embankment, with a swamp each side. Before the train arrived the position of the signal had fortunately called the attention of the man in whose charge it was to the fact of some derangement, and a search was instituted, with the result named above. Another broken rail, first indicated by a signal, was discovered only after several days. This break extended upward and forward (in the direction of the traffic) from the bottom of the rail. The parts were so near each other as to leave only a small space—a hair's breadth—between them. In the daytime, when the sun shone, the expansion of the rail would force the parts together, good electrical connection would be made, and the apparatus would work perfectly; at night, on the contrary, the contraction of the rail would cause the parts to separate and interrupt the circuit and the signal would be at danger. A train would also sometimes slightly displace the parts so as to leave the signal at danger, when perhaps the next train would bring them together again. A pair of fish-plates bolted on was the remedy.

To make perfect electrical connection between the rails, a wire extends past each joint, the ends of which are connected to the two rails by a tight-fitting pin in a hole in the flange of the rail. While rails are new, and fish-plates tightly screwed up, this is not absolutely needed, but as soon as they begin to rust there is trouble if the wires be not attached to the rails. I have known signals work for several months with an unwired track, but ordinarily they will do so only a few weeks, even if rails and plates are perfectly new.

The moving of switches off the main track causes an interruption of the track circuit and sets the signal to danger; replacing the switch restores the signal.

Cars may be left on turnouts so near the main track as to endanger trains passing on that track. To prevent collisions from this cause, turnouts are connected with the main track by wires in such a way that if any part of a train stands dangerously near the main line, it will keep the signal at danger. Trainmen must, therefore, take care to push cars

left on turnouts far enough from the switch to clear the signal, when they are sure to leave main line trains room to pass.

When the block signals are continuous—that is, with no spaces between the sections—the safety of trains following each other at short intervals is very greatly increased by *overlapping* the sections. This causes a signal to remain at danger until the train has passed a certain distance (usually about 1,000 feet) beyond the next signal. While a train is running this short distance there are *two* red signals behind it, one at the beginning of the section where the train is, and the other at the beginning of the preceding section. So long, therefore, as trains regard the indications of the signals, they can never approach each other nearer than the length of the overlap.

Signals are placed a short distance (about 200 feet) from the beginning of the section, in order that the engineer of an approaching train may see the signal operate for his train. Should it fail to do so, he is to proceed just as if no signal were there, and protect his train as circumstances may require. He is instructed to at once report such failures, in order that the cause may be removed without delay.

The engineer of every train stopped by a danger signal must report the stop and the cause, *if known* (as for instance, a previous train in section, an open switch, etc., etc.). If the cause be unknown to the engineer, he simply reports a stop from "cause unknown," and it is put in the hands of a repairman to investigate. When he has ascertained the cause (a broken rail, derangement of the apparatus, failure of batteries, or other cause not at first apparent), he returns the report with his explanation. If *he* cannot find out the cause, he also reports cause unknown, and we usually never ascertain. There is a small fraction of one per cent. of such stops at signals Some of these I am morally certain are due to previous trains, open switches, or other legitimate causes; but in the absence of positive proof, do not feel authorized to classify it as such. Sometimes employés accidentally cause stops of trains at signals, and in order to save themselves the consequences, carefully conceal the fact, which is not always afterward discovered, and when this is the case such stops have to be reported unknown.

Every month a strict debit and credit account is made up of the operations of the signals on each division of the road, which shows at a glance what proportion of stops are due to neglect of employés, defective apparatus, unavoidable causes, etc., as well as all legitimate stops. Employés are held to a strict account for all avoidable stops caused by them, and the number has been reduced to one surprisingly small. (In January, February and March, 1886, the ratio of these stops to number of operations was $\frac{1}{3766}$, $\frac{1}{3133}$, and $\frac{1}{11073}$ respectively, on the division where there are most signals.)

Interlocking.—The applications of electricity to interlocking on the B. & A. R. R. are for the purpose of making sure that when a right of way has been given a train to pass through a section at speed, the track cannot in any way be changed until the train has passed entirely off the section. This is accomplished by applying electric locks to the first levers of all conflicting routes, but not to the signals of the route to be used. The locks are controlled by an ingenious form of relay (invented by Mr. C. A. Scott,

of Boston), with two armatures at right angles. One of these is connected with the distant signal, of the route to be used, and the other with the locks for conflicting routes. For ordinary trains the distant signal is not given, and the locks cannot be applied, but if the distant signal is pulled clear, the apparatus is so arranged that when the train enters the section the locks will hold the levers of conflicting routes as long as the train is there. It thus requires the coincidence of two things to apply the locks—a clear distant signal, and a train in the section. This signal is only used for express trains and such others as are to run at full speed through the section.

I come now to the second part of my paper:

An engineer, in considering the use of electricity for railroad signaling or in connection with interlocking, is brought face to face with the following practical questions:

1. Can we depend upon electricity to operate apparatus with certainty and regularity? What special precautions are necessary to secure this result?

2. To what extent are we justified in using it?

3. Does electric apparatus have the tendency to diminish the care and watchfulness employés would use without such adjuncts?

4. Should it be as far as possible *automatic?*

The answer to the first question to some extent covers that to the second. Electric apparatus is certainly open to some sources of derangement, which mechanical appliances are free from. Some of these are exhaustion of material in the batteries employed, breaking of the circuits due to (a) a broken wire, (b) a broken jar in the battery, (c) corroded or rusted connections (which, while they are not actually divided, prevent passage of the current); freezing in winter, evaporation in summer, neglect of proper care, breakage or wearing out of delicate parts of the apparatus, fixed magnetism in iron or steel parts, and some others.

In order, therefore, that we may depend upon electrical apparatus with at least as great safety as upon mechanical appliances, we must adopt such additional precautions as shall meet these particular liabilities to derangement. For this purpose, each application must be looked upon as a special case and be considered by itself. Electricity must be made to watch for its own failures; sometimes this must be done to the extent of using secondary apparatus, the only purpose of which is to show when the principal appliances are out of order. This means in most cases a closed circuit and a constant consumption of material; we do not yet know how to make a circuit, normally open at one point, show an accidental interruption at another point. In many kinds of apparatus the constant circulation of current to the extent necessary for this can be maintained by a small amount of battery, since a very much smaller current will suffice to hold apparatus in position than would be neccessary for its operation. Expense of maintenance may thus be diminished.

The normal position of railroad signals should be danger: the electric current should be made to do something positive in order to indicate safety. A signal showing all clear should require that the track to which it belongs is continuous and unoccupied by any portion of a train, the switches all set for that line and locked there, the conflicting routes

(if any) locked at danger, and that the electric apparatus is in good order *and actually at work.**

If electricity is applied to lock levers of mechanical apparatus (in my judgment one of its most important uses), a lever unlocked should mean that the route it governs is safe for a train to pass, all conflicting routes shut off, and the electric apparatus working in good order.

The principal consideration ought to be, not how cheap apparatus can we get, but how reliable can we make it. Often it is a question of durability alone that needs to be answered. I know of but few railroads or other corporations which adopt strictly this principle of good apparatus at any price, rather than poor and unreliable appliances because they cost little. I have known repeated instances of a first-class corporation buying cheap electric apparatus because of a less first cost, which was soon more than balanced by large expenses for repairs (sometimes to the extent of replacing the whole apparatus with better), to say nothing of its unreliability. In a few cases I have known it to actually pay more money for poor apparatus than better materials and work would have cost at the start. In no class of work is the old proverb, "well done is twice done," more true than in electrical instruments, but there are few who believe it. It is this short-sighted and contemptible policy of attempting to save a little money by the sacrifice of safety and reliability, that stands in the way of progress and perfection of electric apparatus; there is no inducement except the self-respect of him who does the work, for making the *best thing* in the best way. There are a few who will do what they undertake thoroughly or not at all, but though they may have many times demonstrated the different quality of their work, and its lasting character, their life is often a struggle for existence, while competitors who have thrown conscience overboard and principle to the winds, thrive in business and grow rich, for no reason except that they can place their wares in the market at a lower first cost.

Used in the way I have indicated, with proper safeguards, mixed (as an artist once said of his colors) "with brains," electricity is one of the safest and surest of agents, and its occasional derangements need never cause an accident or serious inconvenience.

The second question, "To what extent are we justified in using electricity for railroad signaling?" may be answered by saying that it is largely a question of expense. We know of no way of obtaining small quantities of electricity for constant use in all places so conveniently as from batteries. The maintenance of these is expensive, both for labor and material. If we wish the current to do any considerable amount of work, we must have a large number of these. The expense involved in their care may then be a complete bar to the use of elec-

* An ideal system of signals ought to provide that a clear signal shall insure to a train about to pass through a section at speed that all the switches are set for the main line, and the presence of the train in the section should automatically lock every switch till the whole of it has passed out. Attempts have been made to do this, but so far as I know they all failed. I think the failure due to imperfect apparatus rather than faults in the principle, and I see no reason why a system cannot be devised whereby all switches shall be automatically locked by the entrance of a train into a section and unlocked by its passage out. Of course for a train intending to use any switch, there must be means for unlocking that particular switch for that particular train.

tricity for a proposed purpose.* We shall ordinarily find the best solution of the problem in hand by working heavy pieces of apparatus by mechanical means or man-power, and *controlling* the movements of the operator by electricity.

In the case of interlocking, for example, let the switches and signals (for the most part) be moved by some mechanical means, and let electricity limit the signalman's movements to such as are at the moment perfectly safe and proper.

When a train has accepted a right of way which has been offered, its very presence there should make it impossible for a signalman or anybody else to change the route, or to interfere in any way with the safe passage of the train until the last pair of wheels has rolled off the section. It should, however, always be in the power of a signalman to put a signal at any time to danger and stop a train. It may happen that when a train which has been given a right of way has begun, or even nearly completed, its passage, it is imperative to recall the right of way and hold the train from completing the movement, until such time as the emergency which made this necessary has disappeared. No electric or other device should, therefore, ever be applied to interlocking or mechanical block signals, to lock a signal in an all-clear position, but the locks should apply to the first movements of all conflicting routes, and remain so applied, whatever be the position of signals belonging to the route occupied, so long as such occupation continues. This is, I think, the great field for the legitimate use of electricity in connection with railroad signals, viz., as a controller or governor, to secure the legitimate and safe use of other forces directly working the apparatus. For this purpose, it ought to be applied wherever it can help to secure (or to indicate) an unbroken or unoccupied track until the train using it has completed its passage in safety.

Third.—"Does its use have the tendency to diminish the care and watchfulness employés would use without such adjuncts?" I think not; it ought rather to teach signalmen safe and careful use of their apparatus, since they can normally make no other; for trainmen it ought to teach prompt and fearless occupation of routes prepared for them, in confidence that they cannot be taken away so as to cause disaster. With some employés it may possibly be true that the more precautions which are taken for the safety of life and limb, the more reckless they become, but such men have no legitimate business with the operation of a railroad; for the others, without regard to the laws upon the subject, is it not the duty of every man or corporation employing men in positions of danger to use every possible precaution, within the bounds of reason, for their protection, and to counteract any tendency to too great reliance on devices of this kind by securing better discipline, a more conscientious performance of duty, and better appreciation of the dangers of their business?

* NOTE.—There may be an apparent contradiction between this statement and the principle laid down in the preceding paragraph, but it is only apparent. Here the question is, shall we use electricity or some other agent for the work we have to do? there the question was, what kind of electric apparatus shall we adopt? The first must be decided by consideration of each particular case as it arises. We can answer the second once for all.

Fourth.—Ought it to be as far as possible *automatic*, or like a tool in the hands of some employé? It is a sufficient answer to this question to say that experience has always shown that whenever the forces of nature or mechanical principles can be substituted for human perception or judgment, there is a great gain in certainty and safety. Electric signaling apparatus should, therefore, be as far as possible automatic. The information conveyed by it must be instantly and perfectly intelligible from the first moment when its indication can be of service. If a *visible* signal (as is usually the case), it must be in form, position and size such that it may be seen a long distance.

In location and color, the signal and the background against which it is seen must be such as never to be confounded with something else in the same vicinity. To secure this, it is often necessary to make a special background for the signal to be seen against, or to place it differently from what would be done on general principles. The proper location and details of arrangement must be determined for each separate case.

"A signal displayed at or near the point of danger (say the Mass. Railroad Commissioners, in their report for 1879) is utterly insufficient and unsatisfactory." It should, then, be far enough from the point of danger to allow stopping any train, in any weather or state of the track, before reaching that point. If that be on a curve, the signal should usually be placed far enough back to be seen from a straight line. If the curve is so long that this cannot well be done, an allowance must be made in distance: a similar allowance should be made where a signal stands on an up or down grade, but it should not be placed so far away as to make it likely that any interference with the track can be made after a train has passed the signal at speed and before it reaches the danger point.

Electric apparatus should of itself warn and protect from danger, and not be merely an instrument in the hands of an employé by which he can notify his fellows of danger he has discovered some other way.

Electricity, intelligently used, makes the eyes and hands of its master indefinitely extended, and to those who know how to apply it, is as certain to do its work as steam or water, and, unlike these, can be made to give warning, not only of its own failures, but of those of the hand that uses it.

NOTES ON THE APPLICATION OF RAILWAY SIGNALS.

By G. R. Hardy, Member of the Boston Society of Civil Engineers.

[Read April 17, 1886.]

Automatic signals are used to show to the engineman of an approaching train the conditions of safety or obstruction which may exist in the section of track beyond the signal. Their value usually relates directly to main-road trains and the certainty of a clear way for such a train.

With the station block system, the automatic signal provides protection which is modified by the length of the section and locations of the parts. Such applications of isolated sections almost invariably include some switches. This condition of isolation subjects a train which is

only just drawn inside the signal, which ought then to become a protection to the train, to a danger from a following train which is warned by a signal only immediately in the rear of the first train, while not enough room remains for the second train to avoid a collision. In the hope of avoiding this element of danger, there appears a tendency to locate the signals more remotely in the rear of the usual stopping places of trains, such a distance as would provide a generous protection and warning for the first train against the following train.

A second element appears now, which should modify such a disposition. In order to have the signal faithfully express an unobstructed track it is necessary to so connect the switches that when one is thrown off the signal will warn a train. When the signal shows all clear the train should advance promptly, but unless electric locking is provided it still remains possible to reverse the position of the switch after the train has passed the signal, and in case of a rapid advance, a safe stop may be impossible after coming in sight of this lately misplaced switch. Of course, if a train is in sight or its approach is announced, one would hardly undertake to shift the switch. Therefore, only a limited distance should be permitted between the signal and the most immediate switches. In practice, a distance of between 1200 and 1500 feet is considered best, or one quarter of a mile. When a train is stopped by a station block signal its rear is not protected automatically. This defect is better provided for by the application of the overlapping block system.

Overlapping Block System.—This arrangement gives a signal which show an unobstructed track after a train has not only cleared all the distance between the first and the second signals, but has gone a reasonable distance beyond the second signal. While occupying this last named distance or space of track beyond the second signal, both the first and second signals remain at danger ; but after passing clear of that space the second signal will be at danger. This arrangement of signals is calculated to afford the largest degree of protection of any plan yet known.

The methods of establishing an accurate relation between track and signal are various, but some qualifications ought to have large prominence. A feature of automatic signals is a peculiar closeness to the immediate purpose of the signal ; that is, the all-clear signal, if such a clear way is open, otherwise a danger signal for one of many reasons, but no further indications are presented. No agent or employé appears to explain the obtrusion. Only this is known : the signal shows danger and a stop must be made, and then, in the absence of information, the train may proceed with caution ; caution here meaning only at such a speed as that the train may be brought to a stop clear of any obstruction which may appear on the track.

Automatic signals are commonly understood to include all kinds of signals which are operated by the presence of a train, and include many and various devices in the detail, such as clockwork and rougher mechanism or instruments, either kind of electric propulsion, pnematic, hydraulic or other means of actuation. In general, they may be classified under two kinds. 1. Those that are operated by the action of a train on a track instrument. 2. Those that are provided with a track or rail circuit. This latter class presents an advantage over the others in that one

pair of wheels or one car, either detached or the last car in the train, as the case may be, if remaining in the section continues by its presence there the same protection that was afforded by and for the whole train. Indeed, that method increases the working length of the section by a distance equal to the length of the train, and that too without the usual corresponding disadvantages of such an extension of length of section. Also in a case of a train parting in two the rear end of the train is protected as long as it continues in the section, even though the engine may have passed out to a point that would with the use or dependence on track instruments have released the danger signal behind its train. Lastly, a second train in a section is protected even though the first train may have passed out. The danger in both these cases, with the use of the track instrument system, is increased beyond that of the ordinary risk of operating a road without any signals at all, because the signal by its usual fidelity in warning the conditions of safety soon comes to be regarded as a guarantee of the clear road if it has been released and the danger signal reversed to safety. In respect to the fact of a second train in the section, the questions may arise as to what moment circumstances will discover two trains in a section at one time.

With automatic signals in this country it is considered entirely impracticable to dispatch trains on the road, bound by the iron-clad rule of a positive block for automatic signals. Such a rule would result in frequent blockades and useless delays. Hence the modification by which the permissive block system is practiced, viz., stop for a danger signal and proceed only as the way is known to be clear. With a crowded service or irregular or delayed trains occasions result in a second train getting into a section before the first train has cleared the same section. Now, as the first train goes out, and if it is to reverse the protecting signal by running over a track instrument at the remote end of the section, it does so and removes all protection for the second train, and a third train is invited to proceed without any warning of the obstructing proximity of the second train. This is no imaginary combination, but has been seriously illustrated.

To Briefly Resume.—First, protect stations and stopping places with a station block system, one for each direction of the service, selecting first the locations most used by trains, and at higher speeds, and which afford the most limited range of vision for the engineman. By weighing these various elements, which in their accumulation serve to characterize the more dangerous localities, good judgment and experience will be able to designate those at which such appliances will afford the largest degree of insurance for the outlay. Hardly a full-grown railroad exists that may not, could such insurance be computed, save money enough in wreckage and repairs, and advantages to the service, to continue an increasing annual expenditure until its lines are well protected.

Second. In completing the work thus begun, other independent points, such as isolated switches and junction points, and sharp curves and longer curves on steep grades will be commended to one's judgment as places for the station block applications; and at the same time certain

large stations, where the approaches are for a long distance characterized by the before mentioned elements of yard switches, blind curves, crossings and junctions, it will be seen to be advisable to advance the protection by dividing these approaches into sections, and entering the applications of the overlapping block system, which conforms readily to any already established system of station blocks ; some minor changes and the additional signals are all that are required. In all this argument I am looking at the question as being confined to the track circuit system or its equivalent.

Most automatic signals are now arranged to stand normally all clear, and show red when there is danger in the way. This may be some time improved so as to stand normally at danger, showing red, and open to let an advancing train enter, which would be a more logical system, but its adoption is just now attended by some undesirable complications which hardly warrant such a change. One of the first track instrument systems used two signals, a second or tell-tale signal being about 1,000 feet beyond the first, at the entrance to a block, and by its mechanism standing at danger if the first was all clear, and changing to all clear after the first went to danger, which occurred as the train actuated a track instrument located opposite the first signal.

The form of signal is an important element, and simplicity should not be lost sight of. The common form of red disk or banner to indicate danger is quickly comprehended, and sufficiently conspicuous, as by common consent that color is so considered, and also its marked contrast with ordinary backgrounds is better than any other. Too large a variety of forms is undesirable, and perplexing to the engineman ; all should harmonize together and follow some definitely marked system. Depending solely upon color is questionable practice, and with the color-blind its consequences are fatal. Form or position assisted by color are now recognized as more acceptable. The logical sequence of natural signs and certain previous conditions leads up to the present features of consistent and not too complicated signaling. The natural use of the color red, for instance, accepted by all mankind and some lower animals as a danger signal, leads to its almost universal adoption in that capacity. As making the best contrast by day, the clear white is used for all clear; but at night, a green light, complementing the red light, makes the safest running signal, and is less in danger of being confounded with the village lights, which might be presented in the range of view.

The form of a signal may be drawn from natural practice, that is, in order to stop a train vigorous motion across the track or nearly horizontal are quickly understood ; from such habits one regards a horizontal position as indicating stop and a vertical position or movement as meaning all clear. Retaining closely the horizontal and vertical features, as having distinct meanings, and we lead up to an appreciation of the semaphore with its horizontal stop and dropping to an all-clear or nearly vertical position. With this argument we should be inclined to use the semaphore for automatic signals ; but with automatic signals worked entirely by electricity, or by electricity and clockwork, it is found better to use the disk signals, on account of the difficulty of providing a sufficient actuating force to move the

semaphores when the usual counter-balancing has been destroyed by accumulations of snow or ice, which difficulty exists in a very much less degree with disk signals rotating on a vertical axis or on a horizontal axis, when inclosed in a case with glass front protecting them entirely from the weather, although liable to be covered with snow in case of damp storms. When the track circuit system is reinforced by power from a pneumatic apparatus, then the force is considered sufficient to move the regular semaphore signals. Such applications have been extensively experimented with, and involve the running of a pipe to convey the compressed air, with machines at intervals of a number of miles to compress the air, also about the usual amount of wire, such as would be required for electric track circuit alone.

Another point in the use of semaphore signals automatically is this :

Most of the applications, so far, with automatic semaphores have been with that form of signal which, when united with interlocking, means a positive stop, and it would seem to be more consistent to avoid such a use of the absolute stop signal, either by the adoption of some distinct form of signal—not a semaphore—or by the use of the dove-tailed semaphore, such as is used for a distant signal.

No railroad can afford to dispatch trains with positive orders not to pass a semaphore stop signal, if such a signal is provided to work automatically, and if the permissive block rule is granted for a form of signal which is automatic in one location while subject to all the uncertainties of electric appliances, and in another location is under the authoritative control of a signalman, it seems that the controlling value of the signal is exposed to strain. It might some time be claimed by an engineman, arraigned for ignoring the latter at an interlocking application, that he thought it was one of the automatics which the permissive block rule would allow him to pass. Indeed, there is but one difference in the rules relating to a danger automatic signal and a distant semaphore—namely, at the automatic signal for danger *stop* and proceed only as the way is known to be clear, while with the dove-tailed distant interlocking semaphore, the rule, when the signal is horizontal, is to proceed only as the way is known to be clear. It is not the purpose of this argument to claim that automatics should be dove-tailed semaphores rather than disk signals, but that if it is deemed necessary to use automatic semaphores, then by all means use the dove-tailed signal in preference to the positive stop semaphore signal.

There seems to be fair grounds for reasoning that automatic and interlocking signals occupy distinct fields of protection, and only overlap one another in their effects under certain circumstances. While interlocking is an old and tried institution, automatics are unique in their character. They are an American's attempt to accomplish cheaply what an Englishman does at large expense, namely, to so block the road as to keep irregular or delayed trains from accident. They are indeed a most valuable substitute, and obtain for the line using them almost the perfect safety which the English lines attain by sectioning the roads with men in towers provided with semaphore signals. While our lines are long, with less frequent stations and fewer connections with switches, the lines on the other side have frequent stations and junctions, all of which

must be provided with interlocking at the outset, leaving only a minimum number of extra towers necessary to quite evenly block out the road for the same purpose of keeping trains well and safely separated. Such a system of blocking is positive, and is all done by semaphores ; but not so with us, though the automatic is intended to accomplish much of the same kind, and with rail circuit it may be safely claimed to do more by continuing it through and under the interlocking application ; yet it must ever continue to do its work with a permissive in the place of a positive value. Its use is to indicate danger, and this only, and its position at safety is not an order to proceed, only the permission.

With the semaphore this style is changed, a signalman in attendance at the tower directs by the aid of the machine all the movements which involve conflicting routes. The geography of the road, known to every competent runner, includes at this place a possibility of trains crossing his route, either those of other lines or some switching or new directions on his own line. This district through which he is to pass is guarded by stop signals, semaphores horizontal. Every avenue of entrance either by side track or back up against traffic right of way on the main tracks should be closed by a stop signal. The whole inclosure is guarded track, and dangerous for any trains without the right to enter, as shown by an all clear signal, but the stop signals are here for a more definite purpose than the automatic, which with its unexpected red signal may be found protecting a broken down train on the road. The automatic gives warning of the unusual condition of danger on the track of an approaching train, but when the interlocking stands guard the danger exists continually like that of a river running around our city, "Stop unless ordered to proceed." The runner no longer approaches an interlocked district prepared to run until something unusual prevents it, as at the automatic signal, but he now prepares to come to a stop at a definite point unless he can discover an all-clear semaphore signal. The home signal should be located at the fouling point first reached, that the engine may come close to it but not pass it, while the red automatic signal and the horizontal distant semaphore both agree in indicating that the train may proceed only with caution, possibly protecting a train by so doing. The all-clear automatic has no reference to the next signal ahead, but the all-clear distant semaphore furnishes a large assurance that the next home signal has been pulled and is now open. Again the semaphore home signal may be open for an approaching train—when it should be closed if the signalman had not failed of his duty to protect a train which had not passed out of the district—and a red automatic signal covering the same district may be used to warn the approaching train of such a condition. When by reason of close proximity of interlocking machines, the distant signal for one tower extends back to the next tower, it is usually placed on the same post as carries the home signal for the same route at the latter tower ; but the home signal being the controlling sentinel at that place, is placed the higher on the post, and the two signals are so slotted together that although the tower man may pull his distant signal it still will remain horizontal unless the other tower man lowers his home signal. At a succession of towers provided only with home signals, trains could hardly approach and pass through curved yards at a speed much over 20

miles per hour, but when in addition distant signals are provided with reasonable laps, unlimited speed may be maintained.

It is of primary importance that the signal operator should always have power to put back the signal to its normal position as soon as he pleases, even to the extent of throwing up a signal in the face of an approaching train, which might be necessary on account of the sudden development of an obstruction in that route. Any system of signals which is arranged to interfere with this freedom is faulty and should not be used. Only this modification is permissible, namely, that with a succession of signals on one route under the signalman, the order of preference will have to be observed, the last signal opened, such as the distant signal, will have to be the first one put back.

The signal should be returned to its normal position as soon as the engine passes. 1st. In order to check any too closely following train. 2d. In order to be prepared to give a new route to any train which may appear on some other route and to prevent the delay which might be caused by a freight train stealing into the first named route, when by right of class of train the train just appearing on a conflicting route should be passed.

Home signals should be placed as the name indicates, just as close to the fouling point as the ground will admit. There is no good reason for making any allowance for room or leeway space between signal and fouling points. Enginemen should appoach the interlocking, prepared to stop at the proper places and draw as near to them as possible, so as to expedite their passage through the interlocking as soon as the signal is given them by shortening the distance to be run. Long trains take advantage of this to get well under the protection of the distant signals. Interlocking makes the neatest application when the fouling space or interlocked district is the shortest, and an ideal application would be a fouling space reduced to a single line crossing the railroad. The nearest approach to this exists when the interlocking simply covers the right angle crossing of one railroad with another.

Many existing applications of interlocking are faulty because of inconvenient arrangement and location of the switches. An intelligent study of a district to be equipped will often discover rearrangement of connections which can be made so as to reduce the outlay and greatly facilitate the train movements. Slip switches with crossing frogs often save a wonderful amount of valuable room and develop facilities which cannot be obtained in any other way. For example, see the yard of the Grand Central depot in New York, under an interlocking machine of 116 levers.

One of the disadvantages of long distances in the interlocking exists when a route starting from a home signal includes a facing point switch a long distance ahead, such a switch, although guarded by a detector bar and facing point lock, may still be subject to the possibility of being changed by the operator after the home signal has been passed by the engine. Conflicting routes which do not always conflict are very common under these stretched out districts, so that sometimes a train may enter and stop for a station or other cause and yet not foul all the other routes. It may become desirable to hold the train there and give another

train a route ; therefore this rule : "*an engine which stops inside the interlocking loses its rights if its signal is put up, and may not move again in any direction without a new signal.*"

The signal should occupy a position directly in the line of view of the engineman as he nears it, and if necessary, bridges should be constructed to attain this object, so as to bring the signal directly over the right-hand rail. Only in very exceptional cases is it permissible to place the home signal of a speed route off one track to the right when that track happens to be a siding not connected with the interlocking. When from the route of approach a number of routes diverge, it is best to unite all the signals of the diverging routes on a post located at the first fouling point, and arrange the signals in regular order from the topmost down, corresponding to the most extreme route to the right, followed by the next one to the left and so on. This rule is arbitrary and might be just as reasonable if the left-hand route was signaled at the top of the post, but natural custom has established this method. It is of great convenience to have the rule strictly adhered to in all cases, and once understood no trouble follows. This rule has had its opponents, who have argued that the top signal should always be taken to apply to the most important route, but though the advocates of such practice have argued in its favor for the earlier and very few applications of interlocking which may be introduced, they have, when they came to consider the possibilities of most extensive outlays, and four track junction points, and large terminal grounds, yielded their first desires to the prevailing practice in conformity to a rule requiring no exceptions.

It is far better, in order to favor such speed service by some prominent signal, to resort to the practice of emphasizing the signals for speed routes. This may be done in various ways. 1st. By varying the sizes of the semaphores. This can be made very conspicuous and still remain in proper order on the post. Give the speed route a full-sized arm and give the siding or branching routes small arms. At night light the speed signals with bull's-eye lanterns and light the small arms with reflected light. 2d. Make the use of the distant signal dependent solely and alone on the use of the home signal for the speed route, and oblige all trains for the slow routes to pass the horizontal distant signal.

WOOD PULP AND SOME OF ITS PECULIARITIES.

By Mark L. Deering, Member of the Civil Engineers' Club of Cleveland.

(Read July 13, 1886.)

It is far beyond my ability at this time to go deeply into the subject of wood pulp. A description of it is a matter of much difficulty. To thoroughly understand the material, manner of treatment and chemical agents used in its manufacture to insure uniformity of texture, requires many experiments and unlimited time. What I will say to you, therefore, will be somewhat more in the nature of personal experience and research than in a critical survey of the works of others. I will take only a hasty

glance at the history and nature of wood pulp, and will try and devote the short time allotted this paper to the discussion of the difficulties to be overcome in its successful manipulation in what is known as the Deering seamless barrel.

Pulp originally meant the soft parts of bone and animal structure, especially the marrow. Then the softer portions of certain fruits, until the digested straw and rags used in making paper was called pulp. As wood was used first as an adulterant in paper making, it naturally took the name of pulp, not an inappropriate one.

Twenty years ago I first became interested in this subject, probably from my curiosity at the novel manner of its preparation in a wall-paper factory in New York City. This was known as "chemical pulp," and was treated with caustic soda and steam, and then digested. Very fine wall paper was made of this, and a firm in New York, and others who started in at that time as pioneers in the manufacture of wood pulp, have since made immense fortunes.

The woods generally used are poplar, white and yellow pine, spruce and cottonwood; pulp made from the last-named being by far the best and also much the highest in price.

The general mode of manufacture is to saw the logs up into billets of about one foot long, the bark being then carefully peeled off. After this the billets are boiled in order to extract the sap, and ground by means of special machinery. After being ground it is digested in a vat with linen stock, jute or other material, in order that it may possess the necessary tenacity of fibre. To give consistency and weight, clay is added, which also fills up the interstices and makes the mass present a better appearance. Sizing is very necessary; rosin, glue, starch and sometimes Irish moss are mixed carefully throughout until the requisite adhesiveness is obtained.

The principal uses to which it is put are in newspaper stock, all fine printing papers, wall paper (almost exclusively), water-pails, tubs, wash-basins, ink-bottles, boats, observatory domes and gunpowder.

After six or seven years spent in designing special machinery for barrel making in the largest cooperage in the world, I found that the principal trouble with which we had to contend was the leakage of liquids through the joints, between staves or elsewhere, during shipment. After thinking of this defect for some time, I decided, in 1879, to make a seamless barrel of wood pulp. After six years of constant research and experiment, I have come to the conclusion that this substance is one of the most discouraging to manipulate which has ever been taken in hand by the engineer. The mere mechanical handling of the material has caused many thousands of dollars to be wasted in experiment, and the proper curing or vulcanizing as much more, and satisfactory results are yet to be obtained.

Some of the more prominent examples might be mentioned casually. A certain company in Akron, O., have been trying for two years to make barrels of this treacherous material, and the last I heard they had yet to make their first one. A company in Hartford, Conn., have made thousands of good barrels, so far as appearance was concerned, but their trouble was in the final preparation to withstand the various vicissitudes incident

to the life of a barrel. The difficulty of proper vulcanization was the rock on which they split. An example in this city was a type case factory which demanded a large outlay of capital (something over $50,000), being used in a protracted series of experiments. Notwithstanding the fact that they actually made some good work, they were obliged to go out of business, sell their special machinery and stock for a mere trifle, and give up the conundrum. They couldn't make their ware with any degree of certainty. A company in Brooklyn, N. Y., spent over $100,000 trying to make insulating material in the form of pipes to carry underground cables for telegraph and telephone companies. This was also a dead failure. Many other examples could be given of loss of time and money trying to solve the problem.

In none of the articles enumerated above do the difficulties approach in magnitude those experienced in the endeavor to make a seamless barrel, and I have caused to be placed before you a miniature oil barrel, together with the machine which made it. To show that there has been at least one good barrel made by my process, I will say that this particular one has been filled with refined petroleum for more than five years past.

You will notice that this barrel is in one piece, all the machinery necessary to form the inside having been withdrawn through the bung-hole after the barrel was completed.

The first difficulty I had to contend with was in overcoming the shrinkage. This was exceedingly variable. Sometimes before the barrel was fairly done the chimes and head would draw apart, very similar to the action of cast iron under some conditions. It took six months to discover the cause and prescribe a cure, or rather a preventive, learning all about it at last by pure accident. When that was overcome the trouble was to keep the shrinkage constant throughout the process of drying by means of artificial heat, which was accomplished after many further experiments.

The method of drying was as follows: I built a small oven of wood, like a dry kiln, and generated my heat with a Bunsen burner. This oven held twelve miniature barrels, and I raised the temperature very slowly through the Fahrenheit scale from 100 to about 250 degrees. This treatment was all right so far as the small barrels were concerned; they came out sound and true, and as hard and solid as a rock. It occurred to me about this time, however, to pour some liquid into the barrels. I tried water first and was very much surprised to learn that it would soak through in every direction about as fast as I could pour it in. Refined petroleum was even worse. After some experimenting I found that by soaking the barrels in a kind of varnish, made principally of rosin dissolved in naphtha, then treating the inside with a bath of oil-excluding compound, which formed a sort of enamel on the interior, I had a barrel oil and waterproof. Now I was sure that if I could get this small barrel all right, certainly one of full size could be made on the same plan. Somewhere around here is where I made a mistake, which led to thousands of experiments (and the outlay of much more money than is creditable for me to mention) in my endeavors to obtain results satisfactory and constant.

Some of the engineers present have seen my large machine at work

turning out full size oil barrels, *i. e.*, of 52 gallons capacity, taking the saturated pulp and making it into a perfect barrel without seam or joint, turning out one barrel every ten or fifteen minutes. For the benefit of those who have not seen the barrels in process, I will show by these drawings, reference being had also to one of the barrels, how I managed to get the hole inside of it without adopting the well-known Chinese method of employing a small boy to hold up the head of each one from the inside, and then selling boy and barrel together.

In the first place notice that the mold which forms the barrel has a compound duplex revolving motion, both speeds alike (about 40 revolutions per minute) the frame which carries the mold having a direct revolution about an axis lying in a horizontal plane, and the mold proper having its bearings at right angles to the axis of the frame; taking its motion from a stationary internal gear through the medium of two bevel gears, one upon the mold and the other stationary upon a trunnion, which was, in fact, one of the bearings for the frame. The revolving of the frame caused the mold to turn in an opposite direction, while the mold was at the same time revolving in a vertical plane. In short, the barrel was turning around, and at the same time it maintained a circular movement, end over end.

Prior to filling the machine with pulp, a receiver (which was simply a cylinder of steel about 4 feet diameter by 8 feet high) was charged with air and water, by means of an air-pump, to a pressure or about 300 pounds to the square inch. The pulp was of the consistency necessary to cause it to flow freely through a six-inch pipe, standing vertically between the mold and the tank on the floor above. The mold being filled with pulp, the former, or device for deciding the thickness and conveying air and water to the centre of the forming barrel, and to discharge the surplus pulp from the centre of the mass outwardly, was now inserted and expanded, making the bung-hole. The bung-hole being made, the machine was set in motion, and when on the first half turn, water from the receiver before mentioned was admitted into the centre of the now forming barrel, when a pressure of about 250 lbs. to the square inch was obtained. It was held at that pressure for about one minute and thirty seconds. This supplied the forming barrel with water taking the place of that disposed of by centrifugal force, and the water admitted in the barrel kept it soft in order that the fibres might be properly disposed as the machine revolved. At this point I substituted air for water, and with all the pressure I could maintain in the receiver (from 250 to 275 pounds) the water forming a very effective cushion to take the force of the air and transmit the same equally to the layer of pulp behind. The machine revolved about 2½ minutes under the air pressure, when it was stopped and inverted from the position it held when charged. While in this position another connection was made automatically through the bunghole with the tank upon the floor above, the water and pulp that remained loose in the barrel descending to the bottom and being forced out through the opening and into the tank from which it was originally taken by means of the pressure of the air within. The machine was again set in motion, water again admitted through the same orifice as before; the machine stopped and inverted

as before. This operation was again repeated, when the air pressure was withdrawn, the machine stopped in the same position as held originally, the former, or part that made the bunghole, collapsed and removed, the mold opened and the fully formed barrel was taken out.

As soon as convenient the barrels were put into a dry kiln which was heated by a wood fire to a temperature of about 250 degrees Fahrenheit and remained there about 36 hours, being turned end for end two or three times during this period. They were then taken out and carried to the vulcanizing department, which contained a steam jacketed wrought-iron tank filled with liquid. The barrel was inclosed in a cast-iron skeleton frame of sufficient weight to carry it to the bottom of the tank, and insure its immersion in the vulcanizing mixture, mechanism being provided to rotate the barrel while therein. The liquor contained in the tank was a mixture of various ingredients, principally sulphur and oil, and it was heated to a temperature of about 400° to 550° Fahr. The barrel remained in the vulcanizer about two hours, all the time under action of steam of 80 to 100 pounds pressure. They were then taken out and allowed to cool, when a cast-iron bushing was inserted in the pulp, forming the bunghole. Next came the process of enameling the inside with an oil proof compound and painting the outside; the bilge being blue and the heads white, similar to ordinary oil barrels. A common wooden bung being driven in, the barrel was completed.

To give some idea of the strength of this barrel when it was ten minutes old, I will say that two medium sized men besides myself have stood at the same time on the top of one of those barrels, immediately after it was taken from the machine. One peculiarity of the barrels was that they would be far softer and heavier twenty-four hours after completion, if not put in the dry kiln, than when first made. This was because of the absorption by the barrel of the moisture of the air, and showed the tremendous power of the air pressure. A barrel of 52 gallons, with an average thickness of $\frac{3}{4}$ inch, when fresh from the machine would weigh about 75 pounds, and when thoroughly dried would weigh about 30 to 35 pounds.

While experimenting with my vulcanizing mixtures, I accidently discovered that a superior insulating material was the result of a few minutes exposure to the contents of the tank, of a common sheet of pulp, the cost being merely nominal, while the quality was pronounced far superior to the best hard rubber or gutta percha. I also succeeded in making a very good quality of sole leather by a little different process. So good, in fact, that a prominent shoe manufacturer fairly persecuted me because I would not make it for him, or at least, tell him how to do it.

Of course there has been some curiosity as to the cause which led to the suspension of the manufacture of the Deering Seamless Barrel. While I am free to acknowledge that the subject is anything but a cheerful one, still I feel it is only due this distinguished Society of Engineers that some explanation be made, no matter how distasteful it may be to me. With this I will close the paper and leave it with this Club and the engineers of the world to give a solution to the problem and perhaps some day supply the missing link necessary to perfect success.

In the first place my machine was practical, and made a perfect seam

less barrel. Secondly, I learned the art of making the fibres of the pulp porous enough to allow the water to pass through the mass, and yet with enough adhesive power to withstand an air pressure of 300 pounds to the square inch, and, during the process of drying, I was able to keep the fibres from becoming disengaged from the main body or from each other, and at the same time maintain the barrel in perfect shape when deprived of moisture. These two things were accomplished only after making hundreds of experiments and spending thousands of dollars. The only thing which eluded me and caused the lack of success in placing the barrels on a commercial basis, was the necessary process of giving uniform strength. It is a fact that some of them were not strong enough to withstand the hard usage incident to transportation, and especially transfers from rail to water, or vice versa ; and while a portion of the barrels would come out permanently competent, others, without apparent cause, would break in shipment.

I think I may say in conclusion that the experiments were conducted systematically, and with such measure of intelligence and inventive ability as I was able to bring to bear on the subject.

DISCUSSION OF MR. DEERING'S PAPER—JULY 13, 1886.

Mr. Deering exhibited a sheet of chemical wood pulp paper made from basswood, and was asked why he employs the term chemical.

Mr. Deering : It is made by the wood being properly treated. After the sap is taken from it, it is cut into short pieces, put into a caustic cylinder and heated. It takes about six hours to dissolve it. When it is first dissolved the fibre is very long: then it is shot out. It is like a number of explosions. Finally it is ground up in the regular engine.

Two specimens of paper were then exhibited by Mr. Deering. He explained that one quality was worth about three cents per pound, the other from four and a half to eight cents. The latter makes the finest kind of writing paper. For this purpose from 85 to 90 per cent. of pulp is used and some linen added. Gunpowder is made from wood pulp at Black River, N. Y. It is so inflammable that if you put a match to it it will explode. I think it is worth four or five dollars per pound.

Mr. Deering exhibited a miniature oil barrel, and said this barrel was made five or six years ago. It has been full of oil ever since. The machine in which it was made is entirely of iron. There is a mold inside the shape of the outside of the barrel. The pulp and water go in together. This part is made of perforated brass, so that the water can be pressed through the pulp.

Mr. Barber : What size are the holes in the brass?

Mr. Deering : There are 24 to the inch. In the machine the pressure was in two directions from the centre, and there were two kinds of revolutions. The centre of the mold was the centre of the machine. The centrifugal force threw the pulp out.

Mr. Latimer : How thick could you make the barrel?

Mr. Deering : I could not regulate the thickness. This little barrel is about a quarter of an inch thick. The first one I made cost me about

fifteen hundred dollars. I worked on it for nine or ten months. In some kinds of pulp the shrinkage is enormous. These little barrels used to shrink an inch and a half. They were made from straw pulp. This wood will shrink three-quarters of an inch to the foot. I tried everything to stop shrinkage, but without success. One day I was out of pulp, so I fell back on some that I had in an old tub. I put on a pressure of about 200 pounds. When the process was completed I opened the machine and found that I had a little barrel there and the rest was mush. I found from this that the pulp had to go to a certain stage of decomposition before I could overcome the shrinkage. When I was in a hurry, I put in an agent to hasten decomposition. One of the hardest things to know is how to have the shrinkage constant.

Mr. Baker (looking at finished barrel): Is this lighter than the wooden barrel?

Mr. Deering: No, sir.

Mr. Baker: What is the thickness?

Mr. Deering: About five-eighths.

Mr. Baker: Does painting check leakage?

Mr. Deering: No, it is only an ornament.

Mr. Barber: Can the wood pulp barrels be manufactured as cheaply as the wooden ones?

Mr. Deering: In this state the material is worth about 20 cents.

Mr. Barber: Can you compete with wooden barrels?

Mr. Deering: We can and will in time. This barrel would hold water for a hundred years. You cannot soak water into it. If water is left on top for some time, you can scratch it, and you will find it perfectly dry. The sizing that is put in is waterproof sizing. When I got this I was not looking for waterproof sizing, I was trying to make it hard. The sizing used in this little barrel is perfectly oil proof, it is milk and lime mixed with the pulp as a cement. When dried at about 250° of heat it is perfectly oil and water proof.

Mr. Latimer: When was that oil put in?

Mr. Deering: About five or six years ago. In one of my experiments I was examining a barrel in which I had gasoline, I had a lighted lamp in my hand and I lowered it to look into the barrel, I do not know what became of the lamp. The barrel went into a million pieces, and I had no moustache or whiskers for months afterwards. If, when a barrel is being made. I start the machine and give it ten turns, and then examine it I find the pulp in layers, for ten turns there will be ten layers. The revolving lays the fibre.

Mr. Latimer: What is the difference between the strength of that and the ordinary barrel?

Mr. Deering: I found that I could not get a uniform strength in the mode of vulcanization. I had a stock farm raising cows to supply us with milk, but we were obliged to try some other material.

A Member: If the barrels were used roughly would they break?

Mr. Deering: Yes, sir. We shipped some to New York. Some came back, but others burst on the road. This question of strength is a valuable one to whoever can solve it.

Mr. Barber: Where did they break?

Mr. Deering: Wherever they were struck with great force.

Mr. Hermann: Have you tried the process used in producing parchment paper?

Mr. Deering: Yes, sir; but in no process could I get the material to go over one-eighth of an inch.

A Member: Could you not put something into that pulp to make it tenacious?

Mr. Deering: I might, but I do not know of anything but what I have tried.

Mr. Perkins: Do they not make type cases of pulp?

Mr. Deering: No, sir. Pails are made of pulp, but a pail is a simple article. I think some one will solve the problem. Whoever can solve it will have a valuable invention. I went to five or six chemists and made them a proposition which would pay them one thousand dollars if they could show me how to overcome this difficulty. One chemist worked on it for several months. I paid one chemist a dollar an hour and he looked into various books and offered suggestions from them. I came to the conclusion that I could earn a dollar an hour myself. There are in this country, France, Germany and England 1,600 patents for paint and sizing. I got all of these.

Mr. Latimer: Do you know that they are making cross-ties?

Mr. Deering: It is all nonsense talking about paper rails and paper car wheels. The paper is put in them, but they are not wholly formed from it.

Mr. Baker: In making cross ties you would want tenacity.

Mr. Deering: You can take sheets of paper and cement them together.

Mr. Latimer: I should judge that the question is the question of pressure.

Mr. Barber: The manufacture of carbons used in electric lighting is very similar. One method is to press the material through a hole, another is to force it into the hole under a pressure of about 400 pounds to the square inch.

Mr. Deering: A sheet of pulp could be made into a material like that barrel in two or three minutes.

Mr. Barber: There is a firm manufacturing boats from paper. They are little shells. The sheet paper is probably used.

Mr. Holloway: We are much indebted to Mr. Deering not only for the trouble he has taken, but for the courage he has shown in giving us the details of his experience. We all know something of the personal attention he has given this manufacture, the difficulties he has met and the ingenious methods by which he has overcome some of them. We know that in spite of his indomitable perseverance he has sustained loss and what appears to be for a time failure in this plan, yet he has had the courage to come before us and detail all his adverse experience, and give us very valuable information. It would seem that the principal difficulty he has had has been in the want of cohesiveness in the material, and the problem which waits to be solved is to overcome this by introducing some cohesive mixture. This must be very cheap. There is hardly anything that may not be accomplished by time, money and brains, but the trouble is to make a manufacture a commercial success.

I should think that if a substructure of woven wire were placed in the mould it would give the necessary strength, and the pulp would make it impervious. I dare say one thousand things might be tried and fail. The rapid destruction of the forests in this country necessitates the discovery of new methods for saving wood. The Standard Oil Company bring their timber from the Gulf of Mexico. Soon all the valuable pine timbers will be used up. Something must be done to replace this loss.

Mr. Latimer: This question may command a good deal of engineering talent. All that we can gather will be of value in solving this problem.

Mr. Gobeille: A point that has occurred to me is that all articles manufactured from paper, such as elevator buckets, observatory domes, paper car wheels have something to start with, but Mr. Deering began with the thing itself. Even the Hartford barrel is made in three pieces. It was a pretty bold thing to begin to make a barrel in this manner.

Mr. Baker: Does not this pulp require wood?

Mr. Latimer: It is made of twigs and small pieces.

A Member: Is not straw pulp available?

Mr. Deering: The shrinkage is so great I could not do anything with it. With reference to Mr. Holloway's remark as to my courage in coming here to give the details of my failure, it is a question whether it is a failure or not. It has cost a great deal of money, but I think that if we live ten or fifteen years we shall see the barrel made. Mr. Holloway's idea about the wire is a good one, it has occurred to me, but I am afraid it would not be practical. If you put wire in, it will not shrink as the pulp does. This barrel is about three-quarters of an inch. They are thin when made; the material would shrink away from the wire.

Mr. Holloway: The question of shrinkage had occurred to me. The shrinkage is caused by the water that is held in suspension by the outer skins of the pulp serving as valves. If the pulp could be made in thin sheets it would obviate the difficulty. Mr. Deering said in his paper that he gets out more water by the centrifugal force than by the pressure. The trouble is that the first pressure put on the mold shuts up the openings.

Mr. Barber: Does not the water permeate the pulp?

Mr. Deering: The barrel is full of water when the pressure is let on.

Mr. Latimer: I thank Mr. Deering especially for having brought these products here. I am very glad that these are oil barrels instead of beer barrels. One woman said that to paper we were probably more indebted than to any other manufacture, and especially because it gave us the records of the past. The present age will show us new advantages from its use. It appears to me that the difficulty to be overcome in this matter is the question of pressure. We know that the upper layers of coal are soft, and those much deeper are hard and brittle. If sufficient pressure can be put on the pulp to express every particle of water, I think it can be made of strength adequate to resist any blows.

Mr. Holloway: The value of pressure is great, but no amount of pressure can compress water. Water is incompressible. If Mr. Deering could drive the water out of the pulp, he would have a perfect barrel.

Mr. Deering: I had some time ago an offer from a man to make some car-wheel brakes. He wanted to make them of pulp. We had a hydraulic press, but we never made a shoe. We had not power enough in the hydraulic press to press the whole shoe.

Mr. Latimer: I saw one not long ago when I was in New York.

Mr. Deering: I presume he makes them, but the moisture is not all pressed out. He fills up the fibre afterward.

Mr. Gobeille: At the last meeting of mechanical engineers in Chicago, I saw paper car wheels. They are made of sheets very thin. All the pressure required is to get these sheets very close together.

IMPORTANCE OF ECONOMICAL GENERATION OF STEAM POWER TO THE DEVELOPMENT OF MANUFACTURES IN ST. PAUL.

By F. T. Hampton, Member of the Civil Engineers' Society of St. Paul.

[Read June 7, 1886.]

During the past year public attention has been urgently directed by the city press to the necessity of establishing and fostering manufactures in this city, in order to secure its steady and permanent growth. The great enterprises, like the construction of the Manitoba, Northern Pacific and Canadian Pacific railroads, of which St. Paul was the financial and business centre, have been completed, and the absence of the stimulus which the execution of these great works imparted to all branches of commerce in this city is now being felt. The time has apparently come when St. Paul must seek to be a producing as well as a distributing centre, if she would maintain that rapid progress that has distinguished her career for the past 15 years. To this end her citizens turn their eyes hopefully to manufactures. I propose to consider this evening the most important factor in the development of this new source of wealth and greatness—cheap motive power.

There are four essential elements in the success of manufactures: cheap motive power, cheap raw material, abundant labor and a good market. A great market lies west of us; labor is ready at hand or easily supplied from fields near by. As to raw material, soft woods are abundant, hard woods reasonably so, pig-iron as accessible as at many points now noted for their manufacture, not counting the immense sources of scrap that could be made available here; grain cheaper than at any point east of Mississippi River. These materials alone, if put into marketable goods, would build up an immense population. Furthermore, the climate is favorable to health and vigor; the natural and artificial advantages, as respects water supply and drainage, are not surpassed by any city, and cost of living is gradually approaching the cheapness of eastern towns.

The doubtful element in this question is the expense of motive power. I shall omit in this discussion all consideration of water-power, because we see the flour mills of Minneapolis supplementing their turbines with steam engines on account of the irregular supply of water, and because a water-power for this city implies the construction of vast hydraulic works in the shape of dams, locks, canals and conduits, costing millions of dollars and requiring large expenditures to maintain—a burden which at Minneapolis has been borne by the general Government. We may also abandon all hope of natural gas coming to our relief, as the geological

structure of the country precludes the possibility of such a discovery unless present theories of geologists turn out to be based upon false premises. The only practical solution to the difficulty now visible is the use of coal, according to the highest refinements indicated by thermo-dynamics, and this brings me in immediate address to my subject.

What is the most economical method of generating motive power for general purposes by the combustion of coal, according to the latest investigations and best practice?

No civil engineer can be an idle spectator of what is transpiring in the field of engineering covered by this question, and no busy mechanical engineer can fail to be at some time or other an active participant in its solution. In reviewing the history of the heat engine, we find three principal forms used to convert the energy of heat into the energy of motion: the steam engine, the hot-air engine, the gas engine.

There have been various other mediums used to effect this conversion, such as ether and ammonia engines, but they have long since dropped out of sight of the engineer. Of these three mechanical agents, the steam engine is the most generally—almost universally—employed in transforming matter into its various shapes for the use of man.

The steam engine has been an invention of very slow growth. Though it loomed upon the world over a hundred years ago, for fifty years it was a very primitive creation as a machine, and if we compare its efficiency as a mere heat-engine to-day with what it was in Watt's time, we have nothing to be proud of especially. Our best engines yield a horse-power to 1¾ lbs. of coal per hour, and the old Cornish pumping engine gave a horse-power to 2 lbs. coal per hour. The superiority of the modern steam engine over Watt's engine consists in its mechanical and scientific construction, in the better proportion of its parts in respect to strength of material and the strains to be resisted, in the adaptation of the machine to a special object, and its general make-up and beauty. Within the past 30 years the improvement of the steam engine in these respects has been very great. Some of us, no doubt, are witnesses to these changes. We can recall to our memories the locomotive engine of our boyhood, its up-right cylinders and walking beams, not unlike great grasshopper legs, and its clumsy cog-wheel gearing. It is only a few years back that locomotives with inside connections, V-hook motion and double valves were used everywhere. All these complicated things have passed away, and to-day we have that majestic object, the symbol ef energy and power, the American locomotive, in which every part seems so eminently adapted to its office, and simplicity and efficiency are visible in the minutest detail.

In the stationary engine, we see the same development on scientific and art principles. Every part of the machine has been the subject of much intense thought. The position of the valve box; the form of valve; the governor and cut-off; the fly-wheel and counterbalancing of parts; and the bed-plate or frame, have received minute attention. Expansion, jacketing and condensation have been studied and practiced for about all they are worth. So he indeed is a presumptuous man, who, standing before a modern compound condensing engine, with a nice valve regulation like that of the Corliss type, says that he can improve

upon it. As a mechanical and scientific production, it is nigh perfection. If our presumptuous friend steps into the boiler room, his self-confident air would not be so offensive, for improvement is far more probable in the method of generating steam, though here too, students and inventors have labored incessantly. The grate, the fire-box, the shell and flues, the bridge wall and chimney, the regulation of the draft, improvement of combustion and prevention of radiation, have taxed the resources of the best talent and skill.

And yet with all these improvements the steam engine, as a heat engine, is far from being perfect. To illustrate this fact: if we follow the course of expenditure of one pound of coal in the production of mechanical power in the best modern boiler and compound condensing engine, we find that 18 per cent. of its heat value for power is lost in the furnace, 82 per cent. remaining in the boiler. In passing from boiler to engine, 1 to 2 per cent. is lost, and in passing through the engine doing work, it takes 70 per cent. of the original heat units in the coal to hold up, we may say, the remaining 10 per cent., while the latter does the work. Nine-tenths of the total heat units are lost at boiler in imperfect combiustion in the gases up the chimney, and in radiation and convection, and at the engine it is lost in radiation and in the condenser, the larger part of this total loss occurring in the condenser, and if in a non-condensing engine the loss occurs in the exhaust. These results are for our best condensing engines with high expansion.

For the best non-condensing engines we would realize about 6 per cent.; for *ordinary* non-condensing engine, such as found in the average factory, about 3 per cent.; and when the boiler is inefficient and attendance careless, no doubt, not more than 2 per cent. of the total heat units in the coal are realized in actual work.

Now, while we cannot, under any possible conditions of the present temperature of the earth's surface, realize more than 25 per cent. of the dynamic energy of coal through the agency of steam, it is not encouraging to the engineer that not much over half of the possible theoretical result is yet reached by the best steam apparatus, and that the average steam engine and boiler do not return us more than one-eighth of the possible result.

The prospect of much further economy in the steam engine is not bright; its efficiency may be increased to 16 or 17 per cent., but this result involves the use of very high pressures not permitted with safety by any style of boiler now in use.

Prohibited by this inexorable law from utilizing more than one-quarter of the total energy of coal through the agency of the steam engine, the engineer has looked about him for some agent more liberal in effecting the conversion of heat into motion, and none has promised more than the gas engine. Its discovery marks an important epoch in the history of heat engines, for the principle of its action, as you are well aware, is very different from that of the steam engine. Briefly, a hydro-carbon gas is admitted into a cylinder, where it mingles with a due proportion of air, and is exploded. The resultant gases by their expansive action impel a piston forward, the impulsive action occurring once in each revolution, or once in two revolutions of the machine. This machine has

returned in actual work 22½ per cent. of the total heat units in the gas—more than double what the best steam engine has done, and what is of more importance, is the fact that its field of development is not limited, like that of the steam engine, but is is theoretically possible to convert into work four-fifths of the total heat units of the fuel. This is the horizon which limits our vision of the future possibilities of the gas engine. Even now an important investigation is pending. The heat of combustion of the gas within the cylinder is very great, and in order to prevent the destruction of the machine by this heat, the cylinder is jacketed with cold water, which is in constant circulation. The heat absorbed by this water, till recently, was a dead loss, but efforts are now making to utilize it in forming steam, which is to be used conjointly with the gas in production of power. There is no doubt that the 22½ per cent. will be largely exceeded in the near future. These results are very encouraging to the engineer, viewing the gas engine simply as a heat-motor, but to the manufacturer who looks upon this matter strictly in a commercial light there is a great drawback, at least at present, in the use of the gas engine, and that is the cost of gas.

A little calculation shows how the case stands at St. Paul. Let us take for prices, to manufacturers:

Anthracite, \$6 per ton (2,240 lbs.); bituminous, \$4 per ton; coal gas, \$1.70 per 1,000 feet.

Then for \$1 we could have:

								Foot lbs.
Anthracite,	374 lbs.,	which at	14,000	units of heat to	the	lb.,	give,..	5,226,000
Bituminous,	640 "	"	" 12,000	"	"	"	" ...	7,680,000
Coal gas,	10 "	"	" 20,000	"	"	"	" ...	200,000

We have here definite amounts of heat, costing \$1. Taking a good average boiler and steam engine, returning 6 per cent. of the heat units of coal as work and the best gas engine yielding 22½ per cent., the resultant work would be in the ratio of:

313,560 units of heat, utilized by steam engine, with bituminous coal.
45,000 units of heat, utilized by gas engine, with coal gas.

Or the work done by the steam engine will cost one-seventh of that done by the gas engine, considering only cost of fuel, which is the main thing that concens us. Coal gas is here rated at \$1.70 per 1,000 cubic feet. It is possible, perhaps, under favorable conditions that the by-products of the gas manufacture may be disposed of profitably and the cost of gas largely reduced, but it would have to be sold for 25 cents per 1,000 feet before the cost of the work done by the gas engine would be as cheap as the work done by the steam engine. The general power user can take little comfort from this exhibit. For special purposes, requiring only small plant, and where convenience of handling and cleanliness are regarded, the gas engine will fill a useful field, but to the manufactvrer at large it offers little yet as compared with the steam engine,

As to the hot air engine, its sphere is restricted, like that of the gas engine and its possibilities are limited like those of the steam engine. Its multiplicity of parts and greater weight for same power make it practicable only for small plant and for peculiar conditions. Nothing seriously disputes the sway of steam, at least as long as coal remains near the present prices.

It remains to consider, how shall we get the maximum results from coal, through the agency of the steam engine. In the treatment of this question, I shall not indulge in any speculation of future development in mechanical science, but endeavor to look upon it in a business light, recognizing only the best practice of the day, and which we know to be in the line of improvement. No startling or radical change need be expected in the development of power from coal for many years to come. We must advance by slow degrees. No vantage will the engineer gain over brute matter and mob forces of nature without a hard struggle. And the manufacturer must depend for his success upon the rigorous practice of the small economies which present sharp competition demands.

The manufacturer in St. Paul especially is encouraged in this policy, since in many products the nearness of the field of consumption will compensate for the disadva ntage of long haulage of fuel, and in some manufactures, where the cost of fuel bears a small ratio to the cost of labor in the finished product, the conditions of manufacturing, East and West, would be equalized. Furthermore, the general tendency of the cost of transportation by rail of crude raw material like coal and iron is downward. Half a cent per ton per mile may now be considered as the basis of the tariff on long hauls, and in another decade it may be reduced to one mill per ton per mile.

The lake rates are still lower, and with improved means of loading and unloading vessels, increased depths of harbors, permiting larger vessels, together with the deepening of the St. Mary Canal, the prospect for reduction of cost of fuel in the Northwest grows brighter every year. With this future before him, the manufacturer in St. Paul should awaken to the situation and realize what can be done to place himself more on a par with his Eastern brother.

Our subject involves the consideration of economy in the generation of steam, economy in the conversion of steam into power, economy in the transmission of power.

The construction of the ordinary steam boiler is too well understood by this Society to require much explanation. It is sufficient to say that for use on land they are comprised chiefly under two types—the cylindrical and locomotive boiler. In the cylindrical form the shell is a simple cylinder and the flues extend the whole length of the boiler. The furnace is formed of brick in the setting of the boiler. The draught passes from furnace under the shell to smoke-box or chamber, thence returns through the flues to stack at front end of boiler. The heating surface is made up of interior surface of all the flues and about two-thirds of surface of shell. The locomotive boiler contains its own furnace, and this feature, together with the circulation of the water around the fire-box, constitutes its distinguishing peculiarity. The draught passes from the fire-box through the flues to smoke-box and stack; heating surface is made up of whole interior surface of fire-box and all the flues. One or the other of these types is found in nearly every factory. Without comparing the relative merits of the two boilers, both have the defect of burning the fuel imperfectly and of storing the steam in a single reservoir, which greatly increases the danger of disaster on rupture of any part of the boiler.

The average efficiency of these boilers as usually managed is from four

to five pounds of water evaporated (from 212°) per pound of bituminous coal of 12,000 heat units. During the past 20 years some very marked improvements have been made in the construction of boilers, both as to economy of fuel and safety from explosion. Municipal laws against the smoke nuisance, as well as a desire for gain on the part of the proprietor, may have had something to do with this progress.

I have already observed that a large part of the thermal value of coal is lost in the furnace; in the best of boilers 18 to 20 per cent., and in the average boiler, 35 to 40 per cent. The prime cause of this loss is the lack of sufficient oxygen in the furnace and the consequent formation of carbonic oxide, instead of carbonic acid gas, the product of perfect combustion. Combustion in most furnaces is so imperfect that it is largely a process of dry distillation of coal, like that taking place in the retorts of gas-works. The problem is, how to supply the deficiency of oxygen. It is now generally admitted, I believe, that the introduction of *cold* air at or back of the bridge wall, or, in fact, in any part of the furnace, except through the grate, is a mistake, because the temperature of the gases of combustion is too much reduced thereby to permit the chemical reaction to take place, producing perfect combustion. It is comparatively recent that the true principle has been recognized, and that is, to heat the air before it mingles with the carbonic oxide. It is an application of the principle of the regenerating method to the steam boiler.

To state the point a little stronger, the total heat units in a pound of carbon are 14,500. If burnt completely or to carbonic acid, we get the full thermal value of the carbon, and the *temperature* of the combustion on which the formation of steam depends will be 4,870°, the highest attainable in the combustion of carbon. If, however, the combustion is imperfect and only carbonic oxide is formed, we realize only 4,500 heat units of the pound of carbon and the temperature of combustion is reduced to 2,700°. These are extreme cases. We can never have perfect combustion in the furnace, and there is always more or less carbonic acid formed, but these facts show where we must look for the greatest advances in the generation of steam.

It behooves a manufacturer, therefore, to keep well before him this principle. The room for improvement in steam generation being very great, many patents have been taken out, each claiming to effect from 10 to 25 per cent. saving in fuel, but failing often to fulfill their claims, proprietors of steam power have become very chary of them and look at them askant, as a railroad man regards a new car coupling. But this is unfair, for there is a decided progress in this line of engineering, to which no large manufacturer can afford to close his eyes.

One of the best received improvements in the steam boiler, or rather setting of the boiler, is the Jarvis furnace. It may be simply described as an ordinary brick furnace with flues in the walls, through which air circulates, becomes heated, and is then admitted above the fire and at bridge wall, to mingle with the gases and promote their combustion. It is found that the heat which the air abstracts from the furnace in becoming heated in the flues is well compensated for in the improved combustion of the gases. So perfect is this combustion that all kinds of waste fuel, like fine coal, saw-dust, spent tan bark, etc., are consumed without loss.

In the past decade, a very radical departure has been made in the mode of constructing steam boilers. The change consists in substituting for the single large generating vessel a number of smaller ones. In one form tubes are used as generators, and in another cast-iron shells are used. The water-tube boiler as built by Babcock & Wilcox and by Root, has evidently come to stay. As its name implies, it effects the circulation of water through tubes, which are united in sections by cast-iron end connections, and the several sections being united to a common steam drum above the tubes and to a mud drum at the back and lower end of the boiler. Its heating surface is made up of the external surface of all the tubes. Its relative economy of fuel is 1.00: tubular, 0.9; flue, 0.79: plain cylinder, 0.69; locomotive, 0.85; vertical tubular, 0.8.

The principal objection to the water tube boiler has been the numerous joints. Experience is gradually overcoming the difficulty of keeping these joints tight, and this type of boiler is coming into rapid use in the East, notwithstanding their higher cost. There is one quality about the water tube boiler that deserves particular notice. Considering only the diameter, the strength of a cylinder to resist a bursting pressure being inversely as the diameters, a tube 3 inches internal diameter, with a thickness of metal of $\frac{1}{10}$ inch, is three times stronger with same pressure than a boiler 36 inches diameter with a shell $\frac{3}{8}$ inch thick, and the capacity of the tube to transmit heat is three times greater than that of the boiler plate.

Keeping in view this question of fuel economy, I would, if laying down an extensive steam plant in this city, favor the water tube boiler, combined with the Jarvis furnace, believing that they embody the best results to date in steam generation for all powers from 20 to 500 horse-power or more. Certain conditions may sometimes prevail making this generator less desirable than others, but in general merit it stands at the front.

A word here as to material for boilers may be in place. Our profession is well aware of the conspicuous part which mild steel is now taking in the construction of boilers. This material has proved its superiority to iron for this purpose by its homogeneity. Charcoal hammered iron, unless made with great care, is liable to have a laminated structure, the slag and other foreign matter not being entirely worked out of it under the hammer: the successive folds of the bloom are prevented from welding together, and blisters and other defects result. But Bessemer steel, being rolled from an ingot, which is cast from the liquid metal as it comes from the converter, cannot be otherwise than uniform in its texture. This quality of the metal, together with its greater tenity, permits the use of thinner plates than if of iron, and more rapid transmission of heat. The status of this metal for boiler construction is defined by the United States Treasury Department in its steam boiler inspection laws:

A steel plate of	70,000 lbs.	must stand a	reduction of	area	of	43	per	cent.
" "	65,000 "	"	"	"	"	50	"	"
" "	60,000 "	"	"	"	"	55	"	"

This was a modification of a previous law requiring 65,000 lbs., with a reduction of 53 per cent., and this modification was made on the com-

plaint of manufacturers who declared their inability to comply with the requirement. This act of the United States Treasurer indicates the general state of development of this metal on Sept. 1, 1885. But a remarkably good specimen has stood a reduction of 60.45 per cent., with tensile strength of 64,000 lbs. and an elongation of 26 per cent. in eight inches.

Though some prejudice has been created against the use of steel plate for boilers by its alleged capricious action, specifications are now so exacting that manufacturers are now producing a product far superior to the plate made three years ago. On the other hand, it is well known that the best brands of charcoal iron are hard to obtain, and much that is in the market under that name never was made from charcoal pig and perhaps not even worked under the hammer. In our selection of boilers, therefore, first cost should not be considered. Our motto should be, the best material in the best form, and depend on the saving of fuel to repay the extra outlay. This, I think, should be the principle to govern all civil engineers when called upon to exercise their judgment or influence in this matter.

Supposing that a manufacturer has decided the boiler question, his next step is to determine the best engine for conversion of the steam into power. At this stage of his enterprise he may be bewildered by the multitude of patterns offered him, and is lost to decide what is best for his purpose. Fortunately, the reputation of the builder is largely a guarantee and a protection to the purchaser. Still there are some important principles which every one contemplating the purchase of a steam plant should keep in view.

As high a degree of expansion as possible—that is, useful expansion, should be used. Without expansion only 7 per cent. of the heat in steam is utilized in work with 3 fold expansion, 13 per cent.; with 6 fold expansion, 17½ per cent.; with 8 fold expansion, 20 per cent. When coal, which will give a horse-power to 3 pounds, costs $5 per ton, and water can be had for 3 to 3½ cents per 1,000 gallons, the highest economy in fuel will be attained by the use of the compound condensing engine. Other things equal, we gain by condensation 20 to 30 per cent. in the work done without condensation with same amount of fuel.

This question settled, the details of the machine come in for consideration. The purchaser should seek simplicity of design; fewness of parts; easy accessibility of parts, for examination and repairs; means to take up wear; good proportions, proper counterbalancing, etc. The valve or valves, especially, should command careful study; its perfect action depending upon a prompt admission of steam at beginning of stroke, a sharp cut-off and an equally prompt releasement at other end of cylinder, with a minimum of wire drawing of the steam and as little compression, except what may be necessary for cushion. This action to be had at all speeds. The observance of these principles will enable him to discriminate among the various forms of cut-offs now on the market.

The management of a steam plant, no less than its selection, is one of great responsibility and concern, and it would be supererogatory to dwell on this point; but one thing I may observe, all proprietors of steam power of any extent should realize the indispensableness of the indicator; it should be regarded by them of the same value and with the same

solicitude as the chronometer is regarded by the navigator; one informs the navigator of his position in treacherous seas, the other, if properly handled, may save the manufacturer from financial disaster. At present, the general practice is to leave the manipulation of the indicator to the men in the engine room; but the apparatus should describe the diagrams in the proprietor's office at any time he desires by simply turning a cock or moving a lever, and he should be able to read the diagram with the same facility that he reads the market quotations from a "ticker."

With these diagrams and the weights of coal consumed, an occasional test on the percentage of power consumed by friction of machinery and the quantity of his product, he is in a position to detect at any time an unusual consumption of power and to apply the remedy.

We have supposed thus far that the power has been consumed directly at its source of generation. When manufacturers are widely separated, this is the only plan before us; but as they increase in large cities, certain causes operate to bring them together into one or more large communities; they gravitate to low levels for convenience of railroad transportation, or seek the banks of a river for an abundant supply of water or water transportation; or sometimes one large manufacturing enterprise will attract around it a number of smaller ones which are dependent on that and on each other for their raw material. When this aggregation of manufactures takes place, there is an opportunity of carrying out another principle of economy—and that is economy in the transmission of power. The indications are that at some day St. Paul and Minneapolis will offer a wide field for a test of the relative economy of the various methods of power transmission.

I will briefly notice the method of transmitting power through the agency of steam conveyed in pipes from a central point of generation to many distant points of consumption, and known as the steam distribution system. This method possesses interest to us, not only as a means of transmitting power, but heat for various manufacturing and domestic purposes. If we have a given amount of steam to generate from coal—say 500 horse-power—we see at once the greater economy of producing it from a single plant, with three or four attendants to run it; with cheap facilities for handling coal, ashes and water; less space occupied; less wear and tear, and with skill and system, under a single management, than when the steam is generated by ten different and separate plants of 50 horse-power each, each plant having at least two attendants of inferior skill and intelligence; few and imperfect labor-saving devices for handling fuel and ashes; less system and order; less steam evaporated per pound of coal, and with many extra expenses incidental to separate and smaller plants. Such would be our view in comparing merely the cost of generating steam by the two systems. But in the first method we have to meet the difficulty of distributing the steam from the point of production to the points of consumption. The chief difficulties are embraced under condensation, leakage, metering the steam to consumers and expansion of pipes.

The most extensive steam distribution system in the world is that of the New York Steam Co., and the data which it has established on this

subject will be of the greatest value to all similar enterprises that may be undertaken. To Mr. Chas. E. Emery belongs the credit of surmounting the many obstacles and bringing the work to a successful commercial basis. In its execution, great many obstructions, such as sewers, water pipes, gas pipes, electric conduits and foundations were met with and had to be conformed to by the steam pipe line. These obstacles would be encountered in all cities more or less, but perhaps in no such degree as in New York City. Leakage was considerable, somewhat exceeding the loss by condensation.

This system went into operation in April, 1882, and steam has been furnished constantly ever since. At present its boiler capacity is 8,700 horse-power, located at one station, where provision is made for 16,000 horse-powers, and location for ten other stations have been purchased. The Babcock & Wilcox boiler furnishes the steam. These boilers, of 250 horse-power each, occupy three stories of a building standing on a lot 75 × 120, 16 boilers to a floor, only 35 boilers as yet required. The company has 5 miles of mains varying from 6″ to 16″, and 2 miles of service pipe 3″ diameter. The pipes are laid in brick trenches and insulated with mineral wool; condensation comparatively small. For the 8,700 horse-power the loss from condensation is only 150 horse-power, allowing 30 pounds of water to a horse-power. Good steam coal costs in New York about $3 per ton 2,240 pounds, one pound of which will evaporate 9 pounds of water from 212°, so the loss in 24 hours from condensation would be $5\frac{1}{4}$ tons of coal in a total of 304 tons consumed—about $1\frac{7}{10}$ per cent. Leakage amounts to a little more, the total loss amounting to $3\frac{3}{4}$ per cent. nearly. This would be equivalent to an evaporation at point of consumption of $8\frac{6}{10}$ pounds of water per pound of coal, an efficiency that is not reached by the average boiler in St. Paul and Minneapolis, such plant as at water-works station and in the flour mills of Minneapolis excepted.

If such results have been attained in New York City, where the difficulties of execution have been so great, how much more feasible is such a system in St. Paul and Minneapolis, which are comparatively in their infancy, and where it is possible to anticipate this work before the subterranean street is encumbered with innumerable passages and pipes. If they find it economy there, where the best coal has been loaded on ships for $2.50 per ton, much more so here where we have to pay from $4 to $5 for not as good coal.

I should notice that in the early part of this undertaking in New York, some explosions of subterranean steam pipes occurred which made the general public very timid about them. The real facts are that, as in all such enterprises, when there is a prospect of good dividends, a rival company stepped in, and in using imperfect devices for trapping the condensed steam, or none at all, led to mishap, which brought the whole practice of steam distribution, for the time, into bad repute; but since that corporation withdrew from the field and various details have been perfected by the present company, the value of the system has begun to be appreciated. I believe its introduction into these cities would be a great boon and boom to them, and it would be a wise policy if they, in keeping with the progressive spirit for which they are noted, should place themselves abreast of the times in this engineering advance.

Leaving the systems of power transmission by compressed air, electricity and wire cable to their proper fields, for they have them, I would propose steam distribution as one of the most effective agents in reducing the cost of steam for power and technical purposes, especially to small industries. This system, in conjunction with the best classes of boilers, skillful and better paid service, a greater familiarity by proprietors with their plant and their increasing watchfulness over it, will contribute more towards effecting an economical reform in the production of power from coal than any other means now visible on the horizon of the industrial world.

PROGRESS IN ELECTRIC LIGHTING.

By N. S. Possons, Member of the Civil Engineers' Club of Cleveland.

[Read June 22, 1886.]

I recently had occasion to send an expert to erect an electric light plant in the yards and repair shops of a railroad company. The Superintendent was one of those capable men who desired to learn all particulars relative to the apparatus, and yet was so fearful of the machine you could scarcely get him near it, for he said "The Almighty grappled for a time with electricity, and failing to control it, sent it into the world for man to wrestle with." The romance of our day consists of the wonderful performances of electricity and steam, far outrivaling the deeds of the past; and to this topic to-night, in so far as it relates to electric lighting, I propose to call your attention.

Every mechanic has a fair idea of the almost endless variety of mechanical combinations by which electric light can be maintained, and the lively interest taken by the public in the development of this science is found in the fact that scarcely a month passes but some new system buds into existence. That some companies have a profitable career before them is not an open question; that others will regret that they have rushed after electrical apparatus with less judgment than enthusiasm is equally certain.

The interest excited by the present active progress in invention has caused us to overlook in a measure the early period of forty years ago, when many inventors' attention was turned in this same direction. The names of Straite, Wright, King and a few others are well known, but works recently published fail to bestow upon them their full meed of praise; but it is a recognized fact that many patents of an early day clash dangerously with some modern inventions.

The principal reason why the inventions of the early days failed was the want of a cheap and practicable dynamo; the earlier means employed for generating currents being from batteries. The earlier savants, Elias and Paccinoti, did not dream of generating currents from their machines, but only of utilizing the current to generate motive power, although the motor constructed might have been made available for the former.

The principle which governs the conversion of mechanical into electr-

cal energy, or the production of electric currents, I will endeavor to explain in a simple way. All know, who have given the subject attention, that electric lights are produced from powerful currents of electricity generated in a machine containing magnets and coils of wire, and driven by a steam engine or water wheel. The modern dynamo machine may be summed up as a combination of cast iron and copper wire, certain parts being fixed, while others are made to revolve by mechanical force.

By "Dynamo' is meant machinery for converting the energy of mechanical motion into the energy of electric currents, or *vice versa*. In this definition are only included those machines, the action of which is dependent on the principle of electro-magnetic induction discovered by Faraday in 1831. The name dynamo-electric machine appears to have first been used by Dr. Siemens, and describes a machine, the currents of which were induced in the coils of a rotating armature by the action of electro-magnets, which were themselves incited by the current so generated. Some systems of electric lights require alternating currents, produced in machines which cannot incite their own magnets with a continuous magnetization. A dynamo is, however, a dynamo, no matter whether the magnets are incited by the whole of its own currents or by a part. In so much, however, as every dynamo-electric machine will work a motor we can scarcely regard the dynamo as a generator on the one hand and as a motor on the other.

To understand how it is that by moving a wire so as to cut magnetic lines of force we can generate a current of electricity in that wire, let us inquire what electricity is. A piece of wire through which a current is passing looks in no way different from any other wire ; no one has ever seen the current running along or knows exactly what changes are goi g on there, nor can one tell which way the electricity flows. Until we get some idea of what electricity is, we must not hope to know what a current of electricity is, and when an electric current flows through a wire, the magnetic force resides not in the wire, but in the space surrounding it. This space, commonly known as the field, is full of magnetic "lines of force," and these lines run from "N" pointing pole to the "S" pointing pole of the magnet invisible, their presence being known by dusting filings into the field. When these filings are dusted into the field, they assume the form of concentric circles, showing that the lines of force completely encircle the wire. To set up these magnetic whirls requires an expenditure of energy, and to keep them up requires also a constant expenditure of energy. It is these magnetic whirls, which, acting on the magnets, cause the needle of a galvanometer to assume a position at right angles with the conducting wire. Thus we have Faraday's principle, that by moving a wire across a space in which there are magnetic lines, as the wire cuts across these magnetic lines it sets up magnetic whirls, or in other words, generates a current of electricity in that wire. If, however, a single coil, or ring, be moved along in a uniform magnetic field so that the same lines of force pass through it, no current will be generated. It is necessary that the moving conductor should in its motion so cut the lines of force as to alter the number of lines passing through the circuit of which this conductor forms a part. The more

powerful the field the stronger will be the current generated. The more rapid the motion the stronger the current. Approaching a magnetic field sets up a current in one direction ; receding, a current in the opposite direction. By the use of a suitable commutator or collector, all the currents, direct and inverse, which are produced as before explained, by approach or recession, can be turned in the same direction in the wire that goes to supply the external circuit, thus yielding an almost constant current. An electro-magnet is twenty times stronger than a permanent magnet.

To construct, then, a successful dynamo-electric machine, the following lines should be observed :

Give the armature the greatest length of wire comprising the coils and as large as is consistent in diameter, to avoid undue resistance. Make the field magnets strong and keep the poles near together.

Unfortunately, it is not always possible to realize all the above conditions, as one is incompatible with the other, and many additional conditions must be observed.

Theory shows that if the intensity of the magnetic field be constant, the electromotive force should increase proportionately with its speed. Now, if the iron in the field magnets be not magnetized nearly to saturation, the increase of speed produces nearly the same increase in the strength of the magnetic field. This increase will re-act on the electromotive force and cause it to be more nearly as to square of velocity ; but since the magnetization of the iron is far from the saturating point and not proportional to the magnetizing force, it is found in practice that the enery is proportional to the fourth power of the speed. Consideration forbids too great a rate of speed of the moving parts, and a safer line is followed by a medium speed and most powerful electro-magnets, it being essential that the dynamo maintain a steady current with constant potentials, or as may be better understood, by pressure to preserve all the lamps in the circuit of an even brilliancy. A steady uniform speed is requisite for successful lighting, a gas engine being out of the question ; we need the best sensitively governed steam engine or good water-power.

We can, perhaps, make far closer measurements in electrical matters than is generally understood. A convenient system of describing the capacity of a dynamo by experts has been based upon the fact that the output of electrical energy is found by multiplying the quantity of current (designated ampères) and the difference of potential through which it is moved. This being expressed in volts, the product will be a certain number of volt-ampères, or, as is more usually termed, watts. Since 746 watts equal one electrical horse-power, to this we must add the resistance of the dynamo machine, the friction of bearing, and thereby arrive safely at the actual power absorbed at the pulley of the machine.

Taking incandescent lamps as now manufactured, a 16 c. p. lamp requires approximately 55 watts. Thus, you will note, for every indicated horse-power we obtain 13 lamps, or 10 lamps per net h. p.

Again with lamps (arc) of 2000 c. p. and ten ampères of current and 45 volts of potential, we have about 450 watts, or about four-sevenths of an electrical horse-power.

There is an enormous difference between the relative capacities of machines of different types. Great improvements have been made of late in the capacity of machines, and especially in improving their capacity relatively to the weight of copper in the armature.

Mr. Brush in 1884 increased the capacity of his machine fully 47 per cent. by abandoning the cast-iron ring armature, and substituting in its stead a ribbon armature built of thin ribbons of iron and insulating each layer. Every condition which contributes to the waste of energy of the current reduces the efficiency of the machine.

Mechanical friction of the moving parts can be reduced to a minimum by due mechanical arrangements. But one thing cannot be obviated; because even the best known conductors have a certain resistance, we cannot expect to prevent the heating of the conducting coils, and the more powerful the current generated by the dynamo, the greater does the source of waste become. There is but one way to reduce this, and that is by increasing the size of the machine. For this reason large machines are advocated, not for any admiration of mere bigness, but because large machines, like large engines, may be made more efficient than small in proportion to their cost.

The Brush Co. have recently completed for the Cowles Smelting Co., of this city, a mammoth dynamo for the extraction of aluminum from corundum. This machine possesses the greatest output of any electric machine in the world, its capacity being 3,800 ampères and 100 volts E. M. F., over 500 electrical h. p. The armature of this machine is 42 inches in diameter, and is constructed after the improved type. The ribbon is wound circular, with projecting cross pieces inserted at intervals to separate the convolutions and the better to admit of free circulation, and with projections as support for the coils. These coils, or bobbins, are 16 in number, and are wound in double layers with three-eighths inch copper wire. This ring is mounted upon a hub made from 10 per cent. aluminum brass, and weighed in the rough cast 400 lbs. This particular casting has a tensile strength of 67,000 pounds to the square inch, with an elongation of 5 per cent. The copper comprising the coils weighs 1,000 pounds, and the whole armature and hub 4,200 pounds. The shaft is made from Otis steel, and is 12 feet long by 5½ inches diameter. The field magnets, of which there are eight, weigh in the casting 500 pounds each, or a total of 4,000 pounds: upon each magnet is 750 pounds of insulated wire. The commutators, of which there are two, are 10 inches in diameter, and 12¾ inches long. The cable leading to the binding posts are eight in number, each composed of strands one inch in diameter. This machine weighs fully 10 tons, and is of the type known as the shunt wound, and will run 6,000 incandescent lamps of 16 c. p.

In all systems of artificial lighting, the light is produced by incandescence or glowing of solid particles of matter. The heat necessary to produce this can be arrived at in many ways. Ordinary gas coal consists of combustible gas, freely charged with particles of carbon, which, becoming highly heated by the gas, glow and produce the light. If the solid particles are removed the combustion of the gas produces no light: as for instance, if gas is mixed with a sufficient quantity of air it oxidizes, and, while we obtain a greater degree of heat, we get no light at

all. Again, if we burn pure hydrogen gas, a flame giving greater heat will be obtained, but no light, because the hydrogen contains no solid particles. We see, therefore, to produce light we must heat a solid body to incandescence.

Solid bodies can become heated by the passage of a current of electricity through them. There is a class of conductors along which a current of electricity can be made to flow, as a current of water through a pipe. There is also a class called insulators along which currents will not flow. No substances are quite perfect either way; the best conductors offer some resistance, and the best insulators, allow currents to leak through them. For our purpose metal and carbon are the classified conductors; highly rarefied or intensely heated air and gases may also be regarded as conductors: and all other solids and air and gas at ordinary temperature may be called insulators. Conductors differ greatly in themselves in facility to conduct currents of electricity. Platinum wire offers 5 to 6 times the resistance of copper of the same diameter and length. The resistance increases for small wire inversely proportional to its cross section.

We now see again that the electric current has given us means of taking heat from the engine and conveying to a distance; that is, to every portion of the wire. So long as the wire is same diameter, the resistance is same, and the heating, therefore, same in all its parts. If, however, we cut our wire, and insert a piece of fine platinum wire in the circuit, in form of a spiral, a great portion of the heat will be concentrated in one spot, and instead of now being uniform, heat will take place in the spiral. We now note that the heat used has been expended in forcing current through a resistance, and not in producing electricity itself. Desiring to concentrate heat at a given point, we place a body of sufficiently high resistance at that point and force so strong a current through it that it glows and gives light. This principle is embodied in electric lamps of all kinds.

The commercial success of electric lighting depends then entirely upon a cheap resistance, either indestructible or easily and cheaply renewed. It would be impracticable to use platinum wire, as this fuses at a temperature of 2,000° C., and further, if heated in air, all known substances oxidize or burn away. Carbon, either alone or in conjunction with heated air, satisfies in a measure the condition. It has never yet been fused. In the incandescent lamps of Swan, Edison and Maxim, the resistance used to convert the current into heat is of a fine thread of carbon, wrought to a high incandescence and protected from oxidation by being hermetically sealed in glass bulbs from which all the air has been exhausted. These lamps last for many months, if not wrought to too great heat. In the arc lamp the current is through two carbon rods or pencils which touch each other, end to end, separating by mechanical arrangement in the lamp as soon as the current is established, and continues through the heated air, which is a partial conductor of high resistance. Great heat is produced: the ends of the carbon rods glow with an intense whiteness; small particles of carbon become detached and are heated in the air between the poles and form an arc, which adds to the light. The carbons consume slowly away, and are fed by gravity.

As this arc becomes long the resistance increases; the electro-magnets become weakened, and the rod is released by mechanical means, and the carbons feed.

In describing machines and lamps I have endeavored to give a general idea, not confining myself to any particular system, some of which I regard as good, others actually bad, in order that an idea of the science may be brought to your notice. The possibilities of electric lighting are very great, and I firmly believe that the day of universal electric lighting will be in the near future, and hope to see in every house the incandescent lamp. For while we may have seen failures in the past we have also seen the steady growth of success. Invention after invention has stood the test, not in its experimental stage, but after months of trial.

ABSTRACT OF DISCUSSION, JUNE 22, 1886.

Mr. Holloway: With regard to electric horse-power, I would like to ask, what is the loss between the engine and the resultant? What is the waste?

Mr. Possons: The loss varies in machines of different types. My familiarity with various types of dynamos leads me to believe that the Brush machine as now constructed gives the greatest efficiency. The armatures generate electricity by revolving between two iron pole-pieces. The loss consists principally in the resistance of the wire, the resistance of the armature and the resistance of the frictional bearings. It amounts to 20 per cent.; we get 80 per cent. of the energy expended. Running the motor, we get a double loss. We get 20 per cent. loss in the dynamo, 20 per cent. in the motor and perhaps 5 per cent. in leakage. We get a net efficiency of 55 per cent.

Mr. Holloway: The loss is less than I supposed.

Mr. Barber: Is there loss in the arc machine from leakage of the current?

Mr. Possons: The machines are so constructed as to give a constant current, and variable electromotive force, governed by speed of dynamo. This current is about 10 ampères, and measures the same in all parts of the circuit: hence no perceptible loss. The resistance of a perfectly insulated wire is infinite. I had, recently, occasion to measure the resistance of insulation on the steamer City of Cleveland. There are 17 circuits; the actual resistance on 15 circuits open was 587,000 ohms. Two of the circuits measured 175,000 ohms; there was leak existing there.

A Member: How do you explain that term resistance as applied to electricity?

Mr. Possons: The resistance of a conductor means that property which determines the amount of electricity that can traverse it in a given interval of time from a definite source of electricity. The quality, the physical condition, and the form of the conductor cause the resistance to vary.

Mr. Sargent: I would like to see if I understand that 55 per cent. Suppose we generate electricity at the coal mines, could we deliver the horse-power expended?

Mr. Possons: You could, less the resistance of the wire from the coal

mines here: assuming that you would use the best conducting metal that you could get, you would lose 45 per cent

Mr. Warner: What does 2,000 candle-power mean, and how do you arrive at this measurement?

Mr. Possons: It means the arc in its best condition, that is, measured at an angle of 45 degrees. We arrive at this by a photometric test; but this test is entirely a matter of guess-work, unless one is familiar with it, since the light of the standard candle used is yellow and the arc lamp white.

Mr. Holloway: What do you mean by electromotive force?

Mr. Possons: By electromotive force I mean what engineers call pressure. It takes 45 volts of electromotive force to run each lamp, with the constant current as before explained; hence, we can run as many lamps in one circuit as the dynamo will furnish this amount of pressure for.

Mr. Holloway: Would Mr. Possons explain the feeding of the carbons?

Mr. Possons: I can give you a crude idea. The feeding mechanism of the lamp is composed of differential magnets or solenoids. The current encircling these causes suction of pole-pieces, which are mechanically connected with a lifting finger and clutch-washer. This device separates the carbon, starting the arc. As the carbon burns away, its resistance becomes greater, less current goes around the suction magnets, the pole-piece is lowered, which in turn releases the clutch-washer, and the carbon feeds by gravitation.

Mr. Holloway: You speak of a field. That field is atmospheric. Is it influenced by the location of the dynamo?

Mr. Possons: No, sir. The electricity from the earth is static electricity.

Mr. Sargent: Can you demonstrate the presence of electricity?

Mr. Possons: You can demonstrate it by sprinkling iron filings upon a magnet through which a current is flowing. These filings will arrange themselves about the magnet and assume polarity. The dynamo machine gets better as it gets older. It is assumed that the molecules are working all the time, and they assume a certain polarity. There are no two dynamos made of the same strength. To get a certain output from every machine, we vary from 50 to 100 revolutions.

Mr. Sargent: Till these molecules assume their best position, what gain is there?

Mr. Possons: The machine will gain in six months about one lamp.

Mr. N. B. Wood: To obtain a given result, a machine must be run varying from 50 to 100 revolutions. Does that make any difference in the power?

Mr. Possons: No, sir; the electrical output of the machine is the same.

Mr. Holloway: If a machine was run in vacuum, what would be the result?

Mr. Possons: The same as now, I think.

Mr. Warner: If the machine was in vacuum and insulated, would it generate electricity as well?

Mr. Possons: Yes, sir.

Mr. Wood: We do not look upon electricity as a thing, it is the essence of a thing.

Mr. Barber: You must have connection with the outside air to deliver the current, and also wire to connect it. I cannot conceive of the machine working perpetually unless there is a circuit round.

Mr. Wood: You might have a pipe run all round.

Mr. Warner: If the machine were in vacuum and insulated, would the iron filings you speak of be collected round the magnet?

Mr. Possons: The iron filings simply show the current along the wire, that it was generated in the field of that wire.

Mr. Richardson: With which armature would the output be the greater? You mention two forms.

Mr. Possons: It would be greater with the ribbon armature. In the cast-iron armature you attract focal currents, and in the ribbon armature you have few cross-currents. In the cast-iron armature you get heat. and in the ribbon armature you get very little heat.

A Member: How do you distinguish between capacity and efficiency?

Mr. Possons: By capacity we mean what it is capable of doing. Efficiency is what we gain between the old armature and the new by the same expenditure of power. We run the ribbon armature faster than the other. The amount that a given machine will produce depends upon the size, the resistance, the velocity and the strength of the field magents.

A Member: I have read of three different armatures. One is made in the ordinary magnet form, surrounded with a proper coil and mounted so that it may be rotated in front of the poles of the field magnet, the Siemens armature, in which the coil is wound longitudinally in deep grooves cut into the opposite sides of a spindle of iron; and then there is the ring armature—I believe that is used in the gramme machine. In that, a solid iron ring, an inch or more in thickness, has its coil wound longitudinally in and out.

Mr. Possons: The forms of armatures differ with their types of machines. My explanation relates more particularly to the Brush. The relative position of pole-pieces and magnets governs its shape. The bobbin in the Brush extends in fan shape, the better for cooling purposes.

Mr. Sargent: Some suppose that the electricity resides in the earth, and some that it is connected with the sun-spots. Has anything been determined with regard to its inner nature?

A Member: People formerly spoke of the electric fluid, but investigations show that this is not the correct term. Electric matter is also inappropriate. Some medium that is not matter, but which fills space and apparently is continuous, is proved to exist by the phenomena of light and heat. It is not atomic or molecular in its structure. This medium is so related to matter that the vibrations of atoms and molecules generate waves in it which travel outward in straight lines from the vibrating body with the velocity of 186,000 miles per second. Electrical phenomena are always developed when two different substances are brought into contact, or when two different substances in contact are heated, either by friction or the application of heat. It is proved that the electrified body does in some way affect some medium that surrounds it. The velocity of this movement has been measured in various ways, and has been found to be approximately the same as the velocity of light;

this leads to the conclusion that the medium must be the same in both cases. In the "Encyclopædia Britannica," electricity is defined as a physical condition of ordinary matter that manifests itself in two ways: 1st, by inducing in the adjacent ether a particular condition of the nature of a stress; and, 2d, by being propagated with great velocity in some kinds of matter, which are hence called conductors. All the other observed effects are secondary.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

October 20, 1886: A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:40 P. M., Vice-President L. Fred. Rice in the chair; twenty-nine Members, four visitors present. The record of the last meeting was read and approved.

Mr. Theodore P. Perkins was elected a Member of this Society.

Messrs. N. Henry Crafts, George Alexander, and Joseph R. Worcester were proposed for membership, recommended respectively by H. Manley, H. L. Eaton, E. H. Gowing, B. C. Mudge, D. H. Andrews, John Worcester.

On motion of Mr. Dexter Brackett, it was voted: That a vote of thanks be extended the management of the Fitchburg and Troy & Greenfield railroads for courtesies extended the Society during the excursion to the Hoosac Tunnel. Also to the manager of the Old Colony Railroad, and Mr. Charles S. Bates, of Cohasset, for courtesies extended during the visit of the Society to the Cohasset Water-Works, Cohasset, Mass.

Prof. Gaetano Lanza addressed the Society on the Action of the Reciprocating Parts in a Steam Engine and Modes of Balancing it in a Locomotive.

Mr. Desmond Fitz Gerald gave a Description of the Berlin System of Sewerage, principally taken from the Annales des Ponts et Chaussées.

[*Adjourned.*] H. L. Eaton, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

October 20, 1886:—The Club met at 8 P. M. in the directors' room, Mercantile Library, President McMath in the chair; fourteen Members and two visitors present.

The minutes of the meetings of April 14 and June 16 were read and approved; also the report of the meeting of the executive committee on September 1.

There being no regular programme prepared for the evening, President McMath called the attention of the Club to that part of the proceedings of the recent meeting of the American Society of Civil Engineers referring to the advisability of a closer union of engineering societies.

The Secretary read extracts from the published proceedings, in which the American Society had directed inquiries to be made as to the sentiment of its own Members and that of the engineering societies. No official communication having reached the Club, the matter was discussed in an informal way by Messrs. Moore, Johnson, Seddon, McMath and Potter. The sentiment of the Club seemed to be opposed to any action that might necessitate a change in existing local organizations, but in favor of a union of publications.

Prof. Johnson explained the failure of a raised series of seats at Washington University.

Prof. Potter spoke on the superiority of the steel nail as now made.

It was moved that the President fill up the membership of the Committee on Smoke Prevention and report his action to the next meeting of the Club; carried.

Adjourned subject to the call of the President. W. H. Bryan, Secretary.

WESTERN SOCIETY OF ENGINEERS.

SEPTEMBER 7, 1886:—The 228th meeting was held at 7:30 P. M., President Wright in the Chair.

The minutes of the preceding meeting were read and approved.

Applications to be admitted to membership were received from:

Theodore H. Bacon, Assistant Engineer, Dubuque & Northwestern Railway, Dubuque, Iowa.

Leslie Warren Goddard, Draftsman, 94 Washington street, Chicago.

The following persons were elected Members and Associates:

James Wilbur Carrier, Assistant Engineer, Chicago & Alton R. R., Chicago.

Eugene Dietzgen (Associate), Manufacturer of Engineers' Supplies, 774 Sedgwick street, Chicago.

John Herron, Assistant Engineer, Montana Central Railway, Helena, Montana.

Edwin A. Hill, Acting Chief Engineer, Indianapolis, Decatur & Springfield Railway, Indianapolis, Ind.

Otto Lubring, Manufacturer of Engineers' Supplies, 749 N. Wells street. Chicago.

Otto William Meysenburg, Manufacturer, 185 Dearborn street, Chicago.

George Rosen Simpson, Patent Office, Washington, D. C.

John Townsend, Engineer and Manufacturer, 185 Dearborn street, Chicago.

Mr. E. H. Beckler was transferred from the grade of Junior to that of Member.

The President announced the death of one of the Society's earliest Presidents and one of its most valued Members, Mr. Ellis S. Chesbrough, and that at the next meeting Mr. Benezette Williams would read a Memorial paper.

It was voted that the next meeting should be of a memorial character in respect to Mr. Chesbrough's memory.

Mr. Williams, Manager for the Society, presented a bill from the Association of Engineering Societies, for the first installment of an assessment made August 23, amounting to $159, which was ordered paid.

Professor I. O. Baker read a paper, "Drainage of Large Areas in Illinois."

Papers on the question of pavements on residence streets were presented and read by Mr. L. P. Morehouse and Mr. S. A. Bullard.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

OCTOBER 5, 1886:—The 229th meeting was held at 7:30 P. M., President Wright in the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted to membership was received from:

Mr. Arthur H. Bell, City Engineer, Bloomington, Ill.

The following persons were elected Members:

Theodore H. Bacon, Assistant Engineer, Dubuque & Northwestern Railway, Dubuque, Iowa.

Leslie Warren Goddard, Draftsmen, 94 Washington street, Chicago.

Mr. Benezette Williams read a memorial paper on Ellis S. Chesbrough.

On motion of Mr. Liljencrantz, it was voted that the memorial paper be printed and a copy sent to the family of Mr. Chesbrough.

Remarks on the character of Mr. Chesbrough were made by Messrs. Wright, Morehouse, Artingstall and Jones.

The Secretary read a reply, by Mr. J. Freeman Clarke, to the criticism of Mr. Gottlieb on the paper on "Long Span Bridges," presented by Mr. Clarke at the April meeting.

The Secretary called attention to the portrait of President Wright, which had just been placed in the Society's room.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

AUGUST 10, 1886:—Regular meeting held.

As both the President and Vice-President were absent, on motion Mr. J. H. Holloway occupied the chair.

The minutes of the last two meetings were read and approved.

The report of the committee on the annual picnic of the Club appointed at the last meeting was received and accepted.

The total expense of the picnic was	$42 83
Amount received from sale of tickets	38 60
Leaving a deficiency of	4 23

Which the Club authorized the Treasurer to pay from the Club funds.

The Secretary reported that a number of applications for membership had been received and referred to the committee on membership, but that action had been taken by only one of the committee, the other two members being absent from the city.

Upon motion by Mr. Rawson, it was resolved that the rules should be suspended and that the Club should vote upon the names.

The following gentlemen were then elected active Members: Alfred Clarke, Harry W. King, James W. Pierce and G. A. Wegner.

Resignations were accepted from the following gentlemen: A. B. Richmond, D. Appel, J. B. Merriam, W. M. Day and J. B. Strawn. The name of Mr. William T. Blunt was taken from the roll of active Members and placed on the list of corresponding Members.

A communication was read from Mr. A. Benjamine, of Euclid avenue, Cleveland, asking the Members to discuss the sanitary aspects of the proposed sewer on Euclid avenue.

Upon a motion by Mr. Rawson, the letter was ordered filed and the corresponding Secretary advised to notify Mr. Benjamin that it was not considered advisable for the Club to discuss this subject, as it is understood to be a financial rather than a sanitary question.

Mr. Theodore Rosenberg then read an interesting paper on "The Drainage and Plumbing in Dwellings."

After a discussion of Mr. Rosenberg's paper, the Club adjourned.

C. M. BARBER, Recording Secretary.

SEPTEMBER 14, 1886:—Regular meeting held. In the absence of the President, Vice-President Swasey occupied the chair.

The minutes of the last meeting were read and approved. A letter from President Latimer was read by the Secretary expressing his regret that he was unable to be present and hear the lecture of Prof. Michelson.

Introducing the speaker for the evening, the Chairman said: "By invitation of the Committee on Scientific Pursuits, we have with us a gentleman whose experiments in the field of science have gained for him not only a national but a world-wide reputation."

Albert A. Michelson, Ph. D., Professcr of Physics in Case School of Applied Sciences, then gave an address on the "Velocity of Light in Air and Refracting Media."

The address was received with applause. Upon motion by Mr. Eisenmann, Prof. Michelson was unanimously elected an honorary Member of the Club in acknowledgment of his valuable contributions to science.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. V. October, 1886. NO. 12.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, *on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional titles and many cross-references.*

All readers of the JOURNAL *are requested to aid in making the Index as complete as possible. All notices for this department, and all matter to be here indexed, should be sent to* J. B. JOHNSON, *Manager Index Department, Washington University, St Louis, Mo.*

Aerial Navigation. Gen. Thayer's System of Dirigible Balloons, either moving on wire "balloon-ways," or wholly disconnected from the earth. Fully illustrated, in *Sc. Am.*, Dec. 26, 1885.

Air. *Flow of, through Orifices in a Thin Plate.* By A. Fliegner. Gives formula derived from experiments made with orifices from 3.17 to 11.36 millimeters in diameter. *Van Nos. Eng. Mag.*, Vol. XXV., p. 217.

—— *in Large Towns.* A paper by William Thomson on the injurious effect of the air in large towns on animal and vegetable life, and the methods of securing a salubrious air. *Van Nos., Eng. Mag.*, Vol. XX., p. 488

Air-Compressor, *Notes on a Water-Column.* By Louis Brunin. Describes an invention for utilizing the power lost in allowing water to flow from the upper levels of mines to the lower level to be pumped. *Van Nos. Eng. Mag.*, Vol. XXI., p. 1.

Air-Locks *and Shaft Tubes, The Construction and Testing of.* Advocates the periodic testing of all chambers. Air-locks not to be used over 1,500 days. Shaft-tube good for 5,000 days. By B L. Brennecke. *Engineer*, May 7, 1886.

Aluminium and its Alloys, *in the Electric Furnace.* A lecture before the Franklin Institute describing the methods used by the Cowles Electric Smelting and Aluminium Company at Cleveland, O. Illustrated. *Jour. Frank. Inst.*, Feb., 1886. Description of the same. *Engineer*, July 9, 1886.

Anemometers, *Whirled.* Gives results of experiments made on the grounds of the Crystal Palace with whirled anemometers. *Van Nos. Eng. Mag.*, Vol. XXV., p. 265.

Aneroid Profile. By T. W. Floyd. Describes the method of observation and computation adopted with the anerold barometer on Western surveys. *Van Nos. Eng. Mag.*, Vol. XXVI., p. 273.

—— *See* Barometer.

Aqueduct. *The New Croton.* A series of illustrated articles in *Sanitary Engineer.* Also see *Sc. Am.*, Nov 7, 1885, for map, profile, and interior views of tunnels.

——. *Sanitary Inspection of the New Croton.* A long article abstracted from the report of the New York State Board of Health. *Sanitary Engr.*, May 27, 1886; also *Engr. News*, May 29, 1886, gives interesting data relating to accident in the tunnel.

—— *Of Segovia.* A brief description of the Roman aqueduct at Segovia. *Van Nos. Eng. Mag.*, Vol. XXI., p. 298.

Arch. By A. J. Du Bois. Application of the new method of graphical statics to the solution of stone and iron arches. *Van Nos. Eng. Mag.*, vol. 13, p. 341.

——, *Fall of Béton.* A short description of the béton arch on the Piræus & Corinth R. R., Greece, which fell on the removal of the centring. Illustrated. *R.R. Gazette*, June 25, 1886.

—— *Bridges.* By W. H. Baker. Gives an investigation of the theory. *Van Nos. Eng. Mag.*, Vol. XXII., p. 33.

—— Improvements in the construction of stone arched bridges. *Centralblatt der Bauverwaltung*, 1885, pp. 473, 490, 517.

——. *The Transformed Catenary as a Figure for.* By W. H. Booth. Advocates the use of the inverted catenary for arches, and gives methods of computing the same. *Van Nos. Eng. Mag.*, July, 1884.

Arches. *Employment of Mathematical Curves as the Intrados of.* An article based upon the theory as given in Rankine's civil engineering. *Van Nos. Eng. Mag.*, May, 1884.

——. *Proportion of.* A careful digest by Mr. E. S. Gould of the actual practice of the French engineers in regard to the proportion of arches. *Van Nos Eng. Mag.*, Vol. 28, p. 449.

——. Description of a *skew* arch built at Harrisburg, Pa. *Van Nos. Eng. Mag.*, Vol. XIV., p. 361.

——. *Skew. The Seventh Street Improvement Arches, St. Paul.* By W. A. Truesdell. A description of these arches, the helicoidal method being used. Illustrated. *Jour. Assoc. Engr. Soc.*, Vol. V., p. 317.

——. *Helicoidal Oblique (Skew) Arches.* By J. L. Culley. A simple exposition of the theory and method of designing the templets and twist rules. *Van Nos. Eng. Mag.*, April, 1886. Also details of an actual construction of such an arch in *Proc. Engrs'. Club, Phila.*, Vol. V., p. 212.

——. *Stability of.* By L. E. Ware. Gives Mr. Durand Claye's method of proving by a geometrical construction that any given arch is, or is not, in a good condition of stability. *Van Nos. Eng Mag.*, Vol. XV. p. 33.

——. *Stability and Strength of the Stone.* By G. F. Swain, Endeavors to show the fundamental principles on which the stability and strength of arches depend. *Van Nos. Eng Mag.*, Vol. XXIII., p. 265.

——. *Theory of the Solid and Broad Elastic.* By Wm. Cain. Gives a purely graphical method of treatment. *Van Nos. Eng. Mag.*, Vol. XXI., pp. 265, 353 and 443.

——. *A Practical Theory of Voussoir.* By Wm. Cain. Treats of the effects of the compressibility of voussoirs, discusses different formula and extends the theory to groined and cloistered arches and domes. *Van Nos. Eng. Mag.*, Vol. XX., pp. 52, 97 and 201 ; also Van Nostrand's "Science Series," No. 42.

Architectural Styles, *Sketches of.* By Prof. N. C. Ricker. A fully illustrated series of articles, beginning with the Egyptian style. *Building*, Jan. 16, 1886, *et seq.*

Armored Turrets. Results of the experiments at Bucharest on two model turrets, one French and the other German. Fully illustrated. *Engineering*, March 19, 1886. Also in *The Engineer* for March 5, 1886, where the two systems are more fully described.

Artesian Wells. *Requisite and Qualifying Conditions.* By T. C. Chamberlin. This is a 42-page appendix to the Fifth Annual Report (1883-4) of the U. S. Geological Survey, J. W. Powell, Director. It is well illustrated and has considerable value to persons contemplating such enterprises. Apply to the Director, or to member of Congress.

Blast Furnace Wool, not a fit substance for steam-pipe covering when containing sulphur. Accidents caused by it at Columbia College. *Trans. Am. Soc. Civ. Engrs.*, Vol. XII., p. 253.

Blasting *with Dynamite on a large scale in Italy.* An account of some very successful blasts, in one of which 120,000 cubic meters were removed. *Proc. Inst. Civ. Engrs.* Vol. LXXXII., p. 423.

—— *Operations at Hell Gate.* A general account of the methods, cost, and results, with many cuts. L. F. Vernon-Harcourt. *Trans. Inst. Civ. Engrs.*, Vol. LXXXV., p. 264.

Boilers, *Comparative Tests of.* A report of tests made at the boiler house of the Brush Electric Light Co., Philadelphia. The plants consisted of 10 boilers, 4 Babcock & Wilcox, and 6 return tubular boilers. Tests gave 77 in favor of former. *Van Nos. Eng. Mag.*, Vol. XXVIII., p. 265.

—— *Construction.* A new method of making horizontal tubular boilers by making the shell in two plates of steel the full length of the boiler. *Trans. Amer. Soc. Mech. Engrs.*, Vol. VI., p. 110.

—— *Corrosion of.* By F. J. Rowan. A paper read before the Glasgow meeting of the British Association. Points out some of the causes of corrosion and gives their remedies. *Van Nos. Eng. Mag.*, Vol. XVI., p. 21.

—— *Defects and Remedy.* By A. C. Engert. An article treating of incrustations, smoke and unconsumed gases and priming. *Van Nos. Eng. Mag.*, September, 1884.

——. *Deterioration of.* Some interesting examples given. *R. R. Gazette*, Nov. 6, 1885.

—— *and Engines for High Pressure.* By L. Perkins. Gives plans for working steam with pressure of from 250 to 1,000 lbs. per sq. in. With comments from *Engineering. Van Nos. Eng. Mag.*, Vol. XVII., p. 143.

—— *Explosions, the Cause and the Remedy.* By Thos. Kays, Adopts the Lawton theory of explosions. Gives results of some experiments. Advocates the Lawton diaphragm. *Van Nos. Eng. Mag.*, November, 1884.

——. *Evaporation performance of.* By D. K. Clark. A valuable article; gives results of a large number of experiments with boilers. *Van Nos. Eng. Mag.*, Vol. XVI., p. 243.

——. *Incrustation of.* By. F. J. Rowan. Treats of the incrustation of land boilers using natural fresh water, and of marine boilers using sea water. Gives tables of analysis of boiler crusts and deposits. *Van Nos. Eng. Mag.*, Vol, XV., p. 545.

——. *The Lancashire.* By L. E. Fletcher. Describes the construction, equipment and setting of the Lancashire boilers, and calls attention to some points which are sometimes overlooked. *Van Nos. Eng. Mag.*, Vol. XV., p. 210.

—— *Making.* A series of articles of considerable practical value. By a designer of boilers. Fully illustrated. *Mechanics*, Jan., 1886, *et seq.*

—— *as Magazines of Explosive Energy.* A valuable paper by Prof. Thurston, showing the source of the explosive energy to be mostly in the heated water, and the amounts of such energy in different styles of boilers. *Trans. Am. Soc. Mech. Engrs.*, Vol. VI., p. 199.

——. *Preservation of.* By Rear-Admiral Aynsley. Gives results of experiments on the prevention of deterioration of boilers. *Van Nos. Eng. Mag.*, Vol. XXIII., p. 395.

——. *The Rating of, by Horse-powers, for Commercial Purposes.* A paper before Am. Soc. Mech. Engrs., by W. P. Trowbridge and C. B. Richards. A valuable discussion of the whole question. *Am. Engr.*, Nov. 12, 1885, *et seq.*

—— Report of the Judges on the tests of the Harvard boilers at the fair of the American Institute. *Van Nos. Eng. Mag.*, Vol. XIII., p. 166.

——, *Steam.* A lecture at Cornell University, by J. M. Allen. The subject adapted to young mechanical engineers. *Sci. Am. Supplement*, March 20, 1886.

——, *Steel.* Some astonishing and apparently unaccountable failures of steel marine boilers from cracking into pieces when not in service. Illustrated. *The Engineer*, Dec. 11, 1885.

—— *Tests, Tables for facilitating the calculation of.* The tables are for reducing the evaporation under the actual conditions to the equivalent evaporation from and at 212°. More complete than any heretofore published. By Wm. Kent, in *Trans. Am. Soc. Mech. Engrs.*, Vol. VI., p. 84.

Bridges, *Cantilever, across the St. John's River, New Brunswick.* Centra. Span 477 feet. Full description and cuts showing stages in erection. *R. R. Gazette*, Oct. 30, 1885.

——, *The Sukkur Cantilever, India.* Span, 820 feet. Several new features. Cut given. From *Mech. World*, London, in *Railway Review*, Dec. 12, 1885, also *Engineer*, July 9, 1886.

——, *Continuous Girders.* On the stress produced in continuous girders during launching. Said to be the first published solution of the problem. Illustrated. *Engineering*, Nov. 27, 1885

——, *On the Theory and Contruction of Continuous.* By Mansfield Merriman. The object of the paper is to present some of the main principles and laws and to illustrate this application to the practical designing of continuous bridge XXV. *Van Nos. Eng. Mag.*, Vol. 15, pp. 145 and 193. Also *Van. Nos Science Series*, Vol. XXV.

——. *The Continuous Girder Question.* By Chas. Bender. A criticism on Mr. Merriman's paper. *Van Nos. Eng. Mag.*, Vol. XV., p. 289.

——. *Calculation of Continuous Girders*, analytically and graphically. By **M.** Bertrand de Fontviolant. A lengthy paper, containing a tolerably full discussion of the subject, including, besides the well-known theories, some investigations regarding effect of deformation of piers, and temperature. The paper, however, contains little, especially in the graphical treatment, which has not been given in previous discussions of the subject. *Mémoires de la Société des Ingénieurs Civils*, Sept., '85, pp. 255-348, with 2 plates.

——. *Floor System, for Railroad Bridges.* By W. H. White. A model system described and illustrated, having rerailing arrangements, guard rails, etc. *Trans. Am. Soc. Civ. Engrs.*, Vol. XII. (1883), p. 451.

——. *Formulas for the weight* of iron and steel railway bridges under standard specifications. By Geo. H. Pegram. Five classes of landing discussed, for which constants are evaluated. Results tabulated. Discussion by Whittemore, Wilson, Hutton, Hughes, Cooper, Macdonald, DuBois, Elliot and Burr. *Trans. Am. Soc. Civ. Engrs.*, Vol. XV., p. 85.

——. *Harlem River Bridge, Designs for the proposed*, at One Hundred and Eighty-first street, which were awarded the first and second prizes. *Engr. News*, also *Sc. Amer.*, March 6, 1886.

The accepted design, as modified from those presented. Cut given in *Engr. News*, April 10, 1886.

Detailed drawings and specifications for the new Harlem River bridge. Also, illustrated description of the design for the Harlem River bridge submitted by Messrs. Vaux and Radford. *Eng. News*, July 31, 1886.

——. *Hawkesbury, Australia.* Drawings of the fourteen competitive designs, three American, ten English and one French, with the corresponding bids. All the American bids being far below the others, the award was made to the Union Bridge Co. *Engineering*, *Eng. News*, May 8, 1886 ; *R. R. Gazette*, April 30, 1886 ; also *Railway Review*, May 8, 1886.

Small map and elevation showing depth of foundation and details of caissons given. These to be sunk to a depth of 185 ft. below high water. Proposed method described. *Eng. News*, Feb. 13, 1886.

Method to be employed in sinking piers to the depth of 185 feet. *Railway Review*, May 15, 1886.

——, *Highway.* By James Owen. A paper of much value to the young engineer, since the practical results from an experience with some 500 bridges of all sizes is given in the paper. Illustrated. *Trans. Am. Soc. Civ. Engrs.*, Vol. XI. (1882), p. 277.

——. *Iron R. R.* A description of those recently erected on a new English road, which may be taken as modern English practice. Two plates. *Proc. Inst. Civ. Engrs.*, Vol. LXXXII., p. 348.

——. A summary of the regulations drawn up by the Saxony Association of Engineers and Arches, relating to the construction of iron bridges. *Van Nos. Eng. Mag.*, Nov., 1884.

Bridges. A sketch of a bridge constructed by an uneducated Mexican laborer from his own design. *Trans. Am Soc. of C. E.*, May, 1886, also *Sci. Amer. Sup.*, July 17, 1886.

——. *See Arch*, and *Drawbridge*.

Bronze Casting. A lecture by George Simonds before the Society of Arts, London. Gives a detailed description of the several steps in producing a bronze statue or artistic model of any kind. Illustrated. *Sc. American Suppl.*, March 20, 1886.

Bronzes, *Manganese.* A paper read before the British Assoc. by P. M. Parsons. Gives characteristics, tensile strength, etc., of the different alloys. *Van Nos. Eng. Mag*, Jan., 1884.

——, *Strength of.* A contribution to the subject from English experiments. *Trans. Liverpool Eng. Soc.*, Vol. V., p. 31.

——, *The Strongest of the.* By R. H. Thurston. Describes the method employed in the research which resulted in the discovery of the strongest bronze. Gives composition and properties of the alloy. *Van Nos. Eng. Mag.*, Vol. 25, p. 126.

Building Stones. A paper by H. A. Cutting, on a series of experiments made to determine the weight, specific gravity, rates of absorption and capability of standing heat of building stone. *Van Nos. Eng. Mag.*, Vol. XXIV., p. 441.

Buffer Stop, *Hydraulic.* Designed and described by A. A. Langley, Eng. Furnishes a constant resistance till train stops. Fully illustrated. *Engineering*, Feb. 19, 1886.

Cable-Making, *for Suspension Bridges.* As exemplified in the East River Bridge. By W. Hildenbrand. A detailed description of the cable-making machinery and of the process employed on the East River Bridge. *Van Nos. Eng. Mag.*, Vol. XVII., pp. 171, 193 and 289. Also *Van Nos. Sci. Series* No. 32.

Cable Roads. By J. Bucknall-Smith. Gives short description of the cable roads at Philadelphia, New York and Cincinnati, illustrated. *Engineering*, June 11, 1886.

——. *Agudio System.* Description of the system proposed by Agudio in 1863; also of a road from Tunis to the Superga, built by Agudio and opened in 1884. *Eng. News*, July 19.

—— *of New York City.* All parts in duplicate; cuts given of machinery and cross-section, showing tunnel construction. *Sci. Amer.*. Jan. 20, 1886.

——, *Inclined*, of Hoboken, N. J. Illustrated description of its peculiarities, especially the grip and brakes. *Sci. Amer.*, Feb. 20, 1886.

—— *in Philadelphia.* Causes of the failure of the system found in the cheap and unscientific character of the yokes. Paper by Prof. L. M. Haupt, in *Phila. Proc. Engr.'s Club*, Vol. V., p. 225.

Calorimeter, *A New Form of.* Determines amount of water in steam by observing the fall in temperature of a given quantity of superheated steam necessary to re-evaporate it. *Am. Engr.*, Dec. 3, 1885.

Cams. A brief treatise on the Steamboat Cam, by Louis Johnson. Illustrated. *Trans. Am. Inst. Mech. Engrs.*, Vol. II., p. 122.

Canals. A paper treating of the causes of ruin to canals and irrigation works, also on the estimated losses from deterioration of irrigation canals. *Van Nos. Eng. Mag.*, Vol. XXI., p. 381.

——. A paper by J. B. Johnson on the relative amount of work done in preparing boats by paddle-wheels and by cables. *Van Nos. Eng. Mag.*, Vol. XXIII., p. 369.

——. Synopsis of the proceedings of the Brussels Inland Navigation Congress; details and illustrations of the principal canal work in Europe. *Engineer*, July 9, 1886; also *Van Nos. Eng. Mag.*, Aug., 1886.

——, *Baie Verte.* By Thos. Guerin. Reply to criticism by Clemens Herschel. *Van Nos. Eng. Mag.*, Vol. XIV., p. 55. Reply to the above. By Clemens Herschel. *Van Nos. Eng. Mag.*, Vol. XIV., p. 150.

—— *The Elbing Hiland, Holland.* The locks replaced by inclines operated by turbines. *Abstr. Inst. Civ. Engrs.*, Vol. LXXXIII., p. 470; also *Zeits. für Bauwesen.* 1885, p. 63.

——, *Manchester Ship.* A summary of the principal features of the canal from Manchester to Liverpool *Engineering*. July 16, 1886. Also, by H. S. S. Smith, gives a short history and details of the scheme. *Van Nos. Eng. Mag.*, Nov, 1884.

Cements. By Gen. Gillmore. Notes on the hydraulic and other cements at the Philadelphia exhibition. Gives methods of manufacture and tables of crushing and tensile strength. *Van Nos. Eng. Mag.*, Vol. 16, p. 261.

——, *American vs. Portland.* An article by F. Collingwood, going to show that for most purposes for which cement and concrete are used in this country, our own natural cements are quite "good enough." *Sanitary Eng'r*, Nov. 5, 1885.

—— *of the Gate of France.* Nature of deposits, methods of manufacture, workings of an aërial cable for automatic transportation, the final uses and products. From *Le Génie Civil*, 19 illustrations. *Sc. Amer. Suppl.*, Nov. 28, 1885.

——, *Hydraulic, Chemically Considered.* Extracts from the annual report of the Chemist of the Engineer Department of the District of Columbia. Seven brands of native and foreign cements compared in strength and chemical composition. *Engr. News*, Dec. 5, 1885.

——, *The Cement Works on the Lehigh.* Brief descriptions of the cement (Portland and Anchor) works and the deposits, with tables of analyses and results of tests, p. 9. Chap. XII. of Report of Frederick Prime, Jr., *Second Geol. Survey of Pa., D. D.*, 1876.

——, *The Louisville.* An account of the location and capacity of the mills on the Ohio River manufacturing Louisville cements, with records of tests of most of the brands, made by the St. Louis inspector, Thos. D. Miller. *Jour. Asso. Eng. Soc.*, Vol. V., p, 187,

—— *Mortars, Their behavior under various contingencies of use.* By F. Collingwood. With especial reference to farther investigation on the change of volume with age and under pressure. *Trans. Am. Soc. Civ. Engrs.*. Vol. XIV., p. 491.

——, *Portland.* By Henry Faija. Treats of the source of strength. *Van Nos. Eng. Mag.*, Vol. XXII., p. 463.

——, *Adhesive Strength of Portland.* A paper by J. J. Mann, before the Inst. of C. E., which refers principally to the adhesive strength of cement, and a description of improved method of determining its quality and value. *Van Nos. Eng. Mag.*, Vol. XXIX., p. 233.

——, *Sewer Pipe.* The methods of its manufacture described, as practiced at Milwaukee, Wis. Illustrated. *Sanitary News*, Oct. 10, 1885.

——, *Testing of Portland.* By I. J. Mann, before the Institution of Engineers. Treats of the color, weight, pulverization, and tensile strength of Portland cement. *Van Nos. Eng. Mag.*, Vol. XVII., p. 17.

—— *Tests.* Report of a committee of the Am. Soc. of Civ. Engrs., prescribing a series of "standard tests" for fineness, checking, or cracking, and tensile strength. It would seem to be well for all tests in America to be made by the methods here prescribed in order to enable intelligent comparisons to be made. *Trans. Am. Soc. Civ. Engrs.*, Vol. XIV., w. 475, also in *Engr. News*, Dec. 19, 1885.

——. Answers to eight queries by the government chemist on methods of testing (should be tested wet) relative strength of Portland and light burned cements, effects of alumina, magnesia, alkali, sulphuric acid. The *Engr. News*, Dec 26, 1885.

——. *On the Mechanical Examination and Testing of Portland.* By Henry Faija. Considers details of manipulation and other matter affecting results in a cement test, and then the properties which a good cement should show. *Van Nos. Eng. Mag.*, Nov., 1884.

——, *The use of.* By G. R. Redgrave. Before the Architectural Association advocates the use of cements instead of lime in all buildings, and gives tables of comparative strength and costs. *Van Nos. Eng. Mag.*, Vol. XXIV., p. 121.

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Also "Exposé Elémentaire de la Nouvelle Méthode de M. Eduard Jäderin pour la mesure des Droites Geodesivues au moyen de Bandes d'Acier et de Fils Métalliques. Par E. P. E. Bergstrand, Ingénieur au Bureau Central d'Arpentage à Stockholm, 1885." This is a forty-eight page pamphlet in French, describing the methods of Mr. Jäderin, with additional tables for reduction. Mr. Bergstrand assisted in Mr. Jäderin's observations. Address the author.

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